(12) **United States Patent**
Hara et al.

(10) **Patent No.: US 8,432,773 B2**

(45) **Date of Patent: Apr. 30, 2013**

(54) **THERMALLY-ASSISTED MAGNETIC HEAD HAVING BANK LAYER BETWEEN MAGNETIC POLE AND PLASMON GENERATOR**

(75) Inventors: **Shinji Hara**, Tokyo (JP); **Kosuke Tanaka**, Tokyo (JP); **Keita Kawamori**, Tokyo (JP); **Daisuke Miyauchi**, Tokyo (JP); **Takahiko Izawa**, Tokyo (JP); **Eiji Komura**, Tokyo (JP)

(73) Assignee: **TDK Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 247 days.

(21) Appl. No.: **12/962,878**

(22) Filed: **Dec. 8, 2010**

(65) **Prior Publication Data**

US 2012/0147716 A1 Jun. 14, 2012

(51) **Int. Cl.**
G11B 11/00 (2006.01)

(52) **U.S. Cl.**
USPC **369/13.33**; 369/13.13

(58) **Field of Classification Search** 369/13.33, 369/13.32, 13.13, 13.17, 112.09, 112.14, 369/112.21, 112.27, 300; 360/59; 385/129, 385/31, 88–94; 29/603.07–603.27; 250/201.3, 250/201.5

See application file for complete search history.

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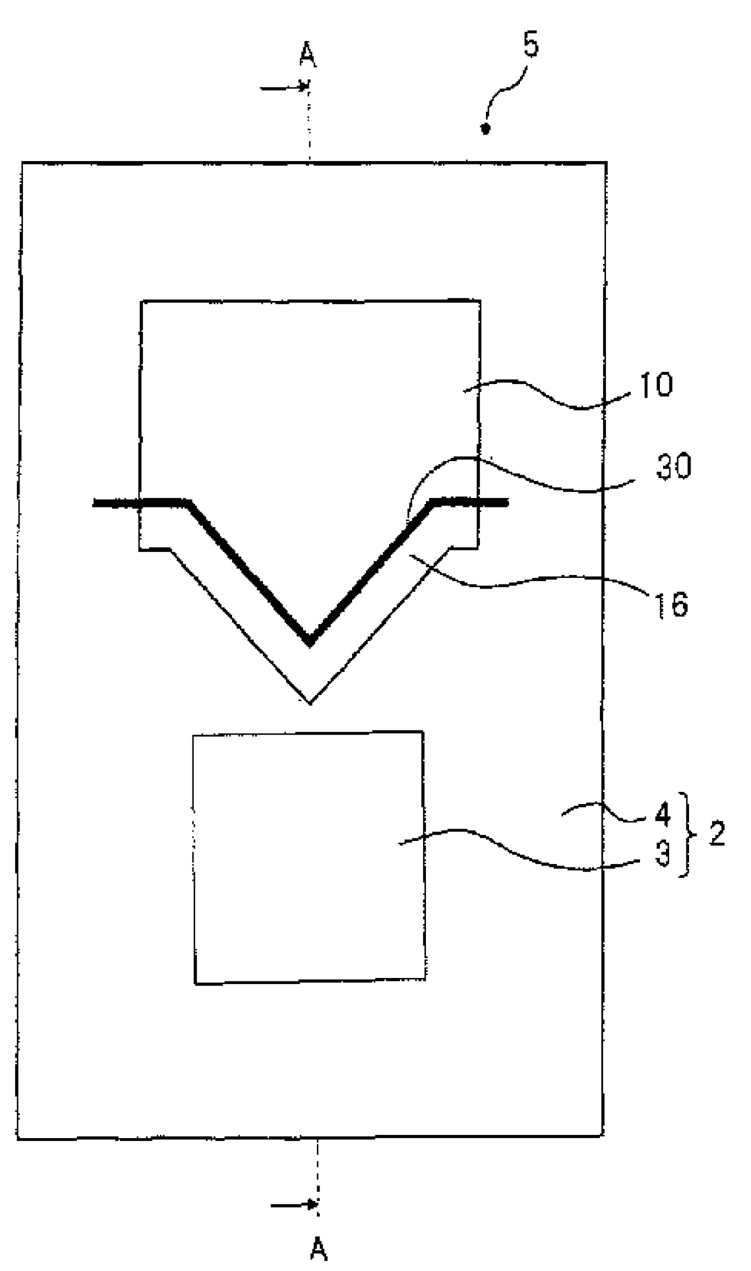
Primary Examiner — Tan X Dinh

(74) *Attorney, Agent, or Firm* — Posz Law Group, PLC

(57) **ABSTRACT**

A thermally-assisted magnetic head that has an air bearing surface (ABS) facing a recording medium and that performs magnetic recording while heating the recording medium includes: a magnetic recording element that includes a pole of which an edge part is positioned on the ABS and which generates magnetic flux traveling to the recording medium; a waveguide that is configured with a core through which light propagates and a cladding, surrounding a periphery of the core, at least one part of which extends to the ABS; a plasmon generator that faces a part of the core and that extends toward the ABS side; and a bank layer that is positioned between the plasmon generator and the pole, and of which an edge part on the ABS side protrudes relative to the plasmon generator.

10 Claims, 13 Drawing Sheets



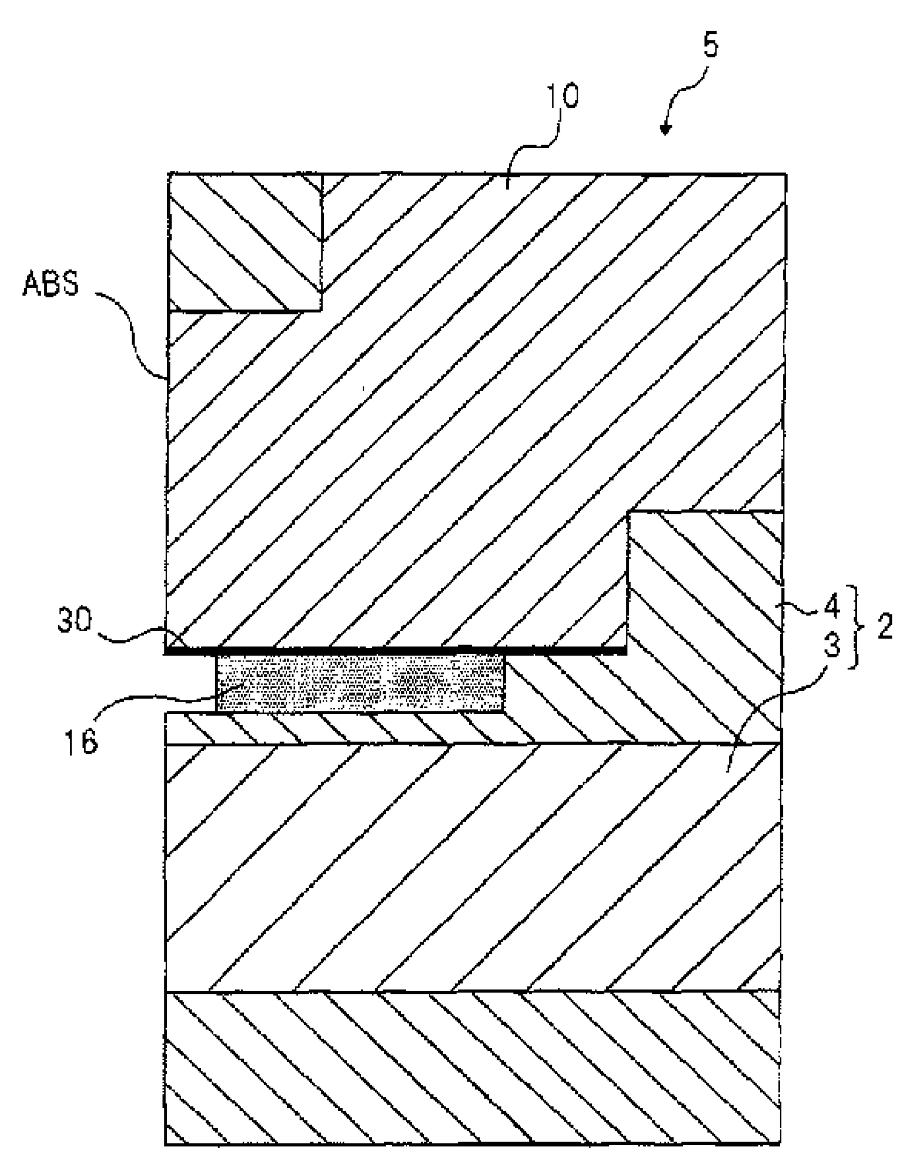


Fig.1B

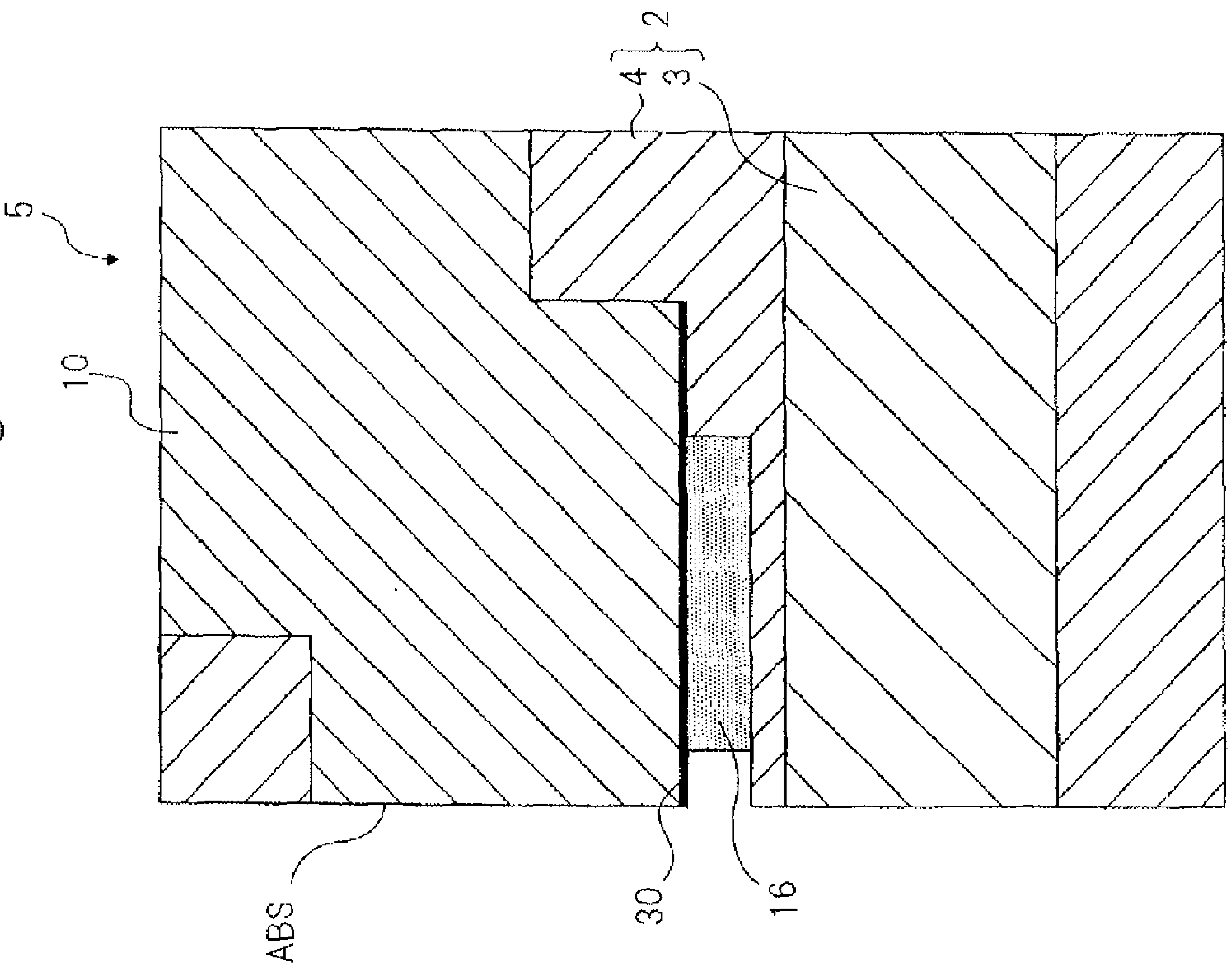


Fig.1A

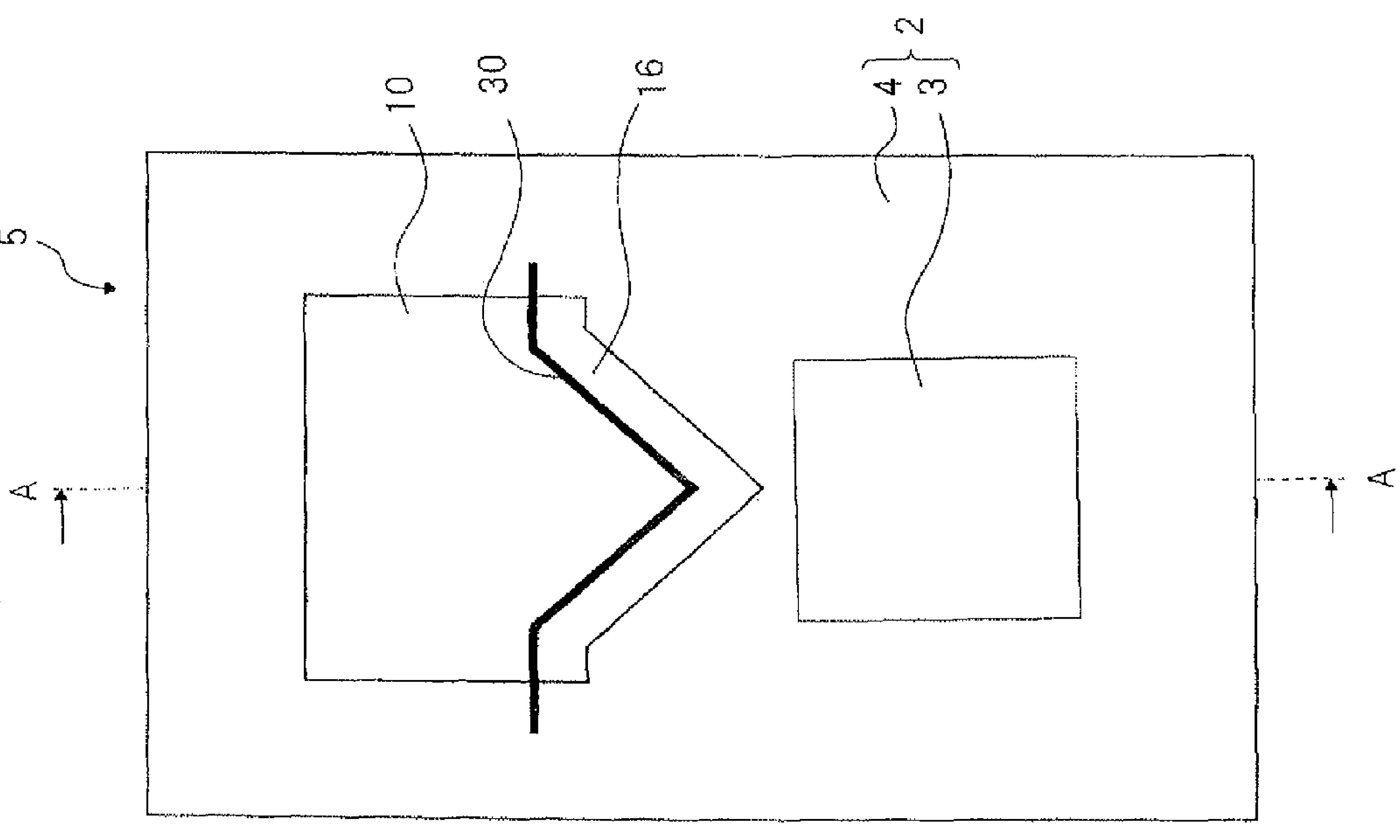


Fig.2C

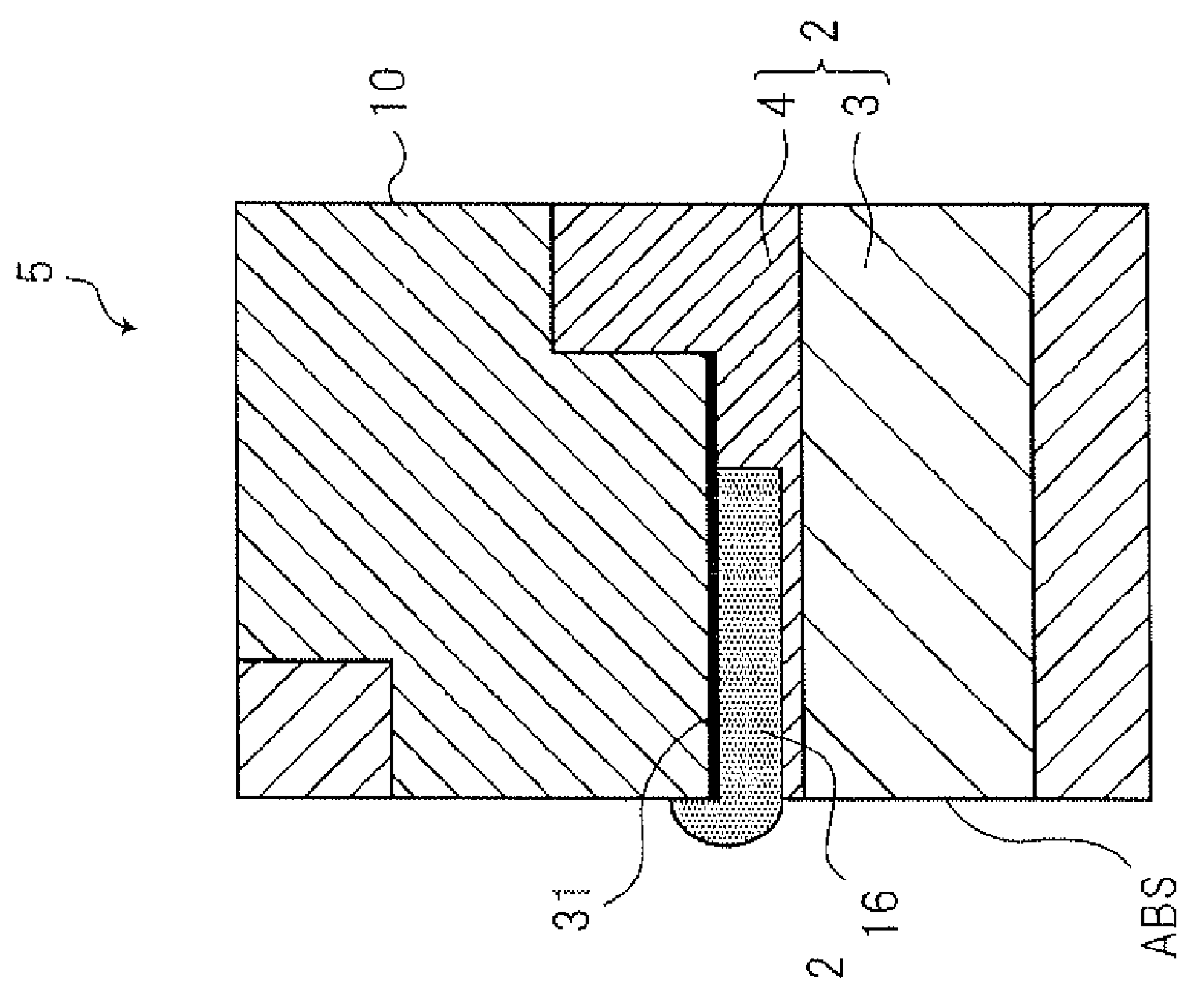


Fig.2B

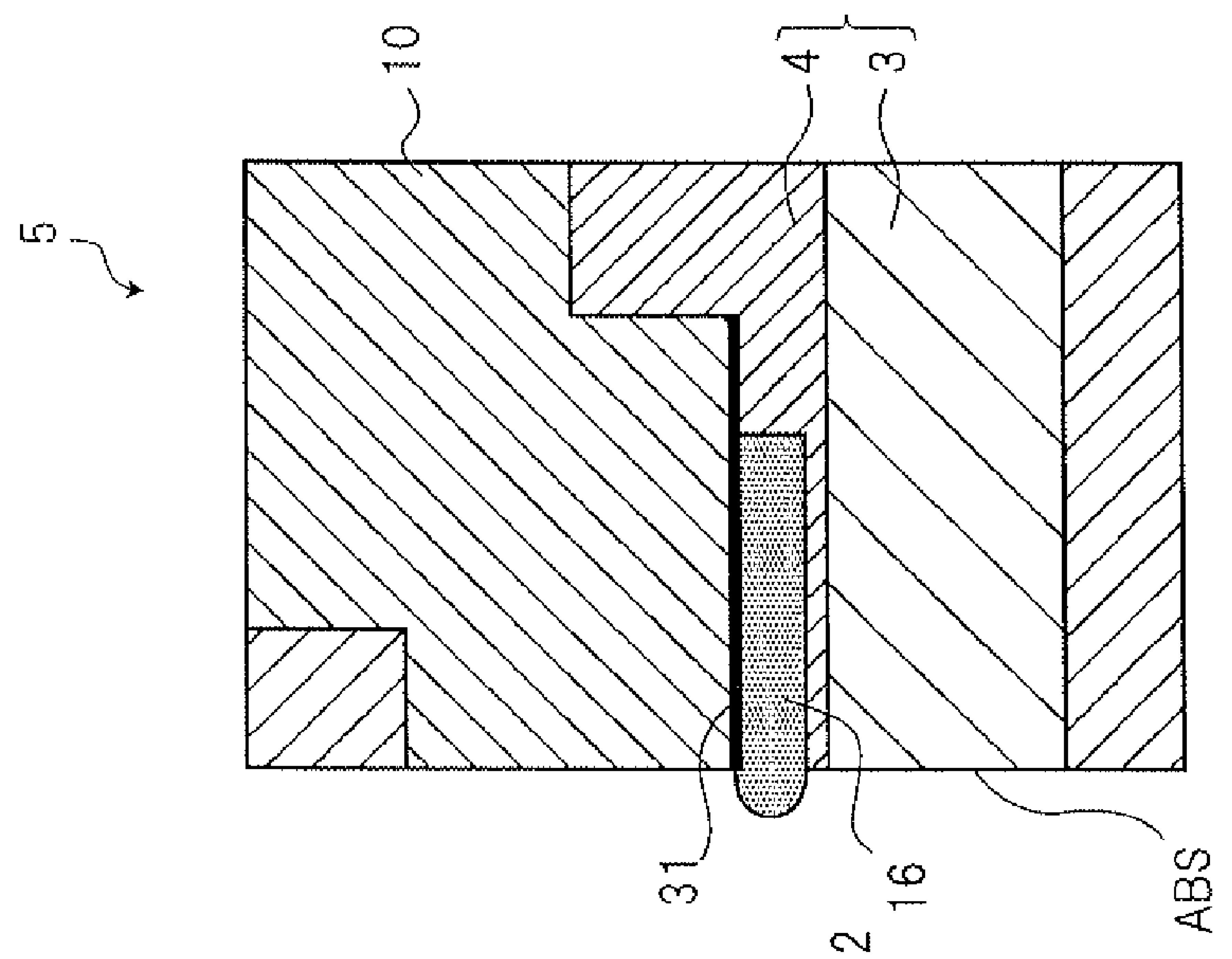


Fig.2A

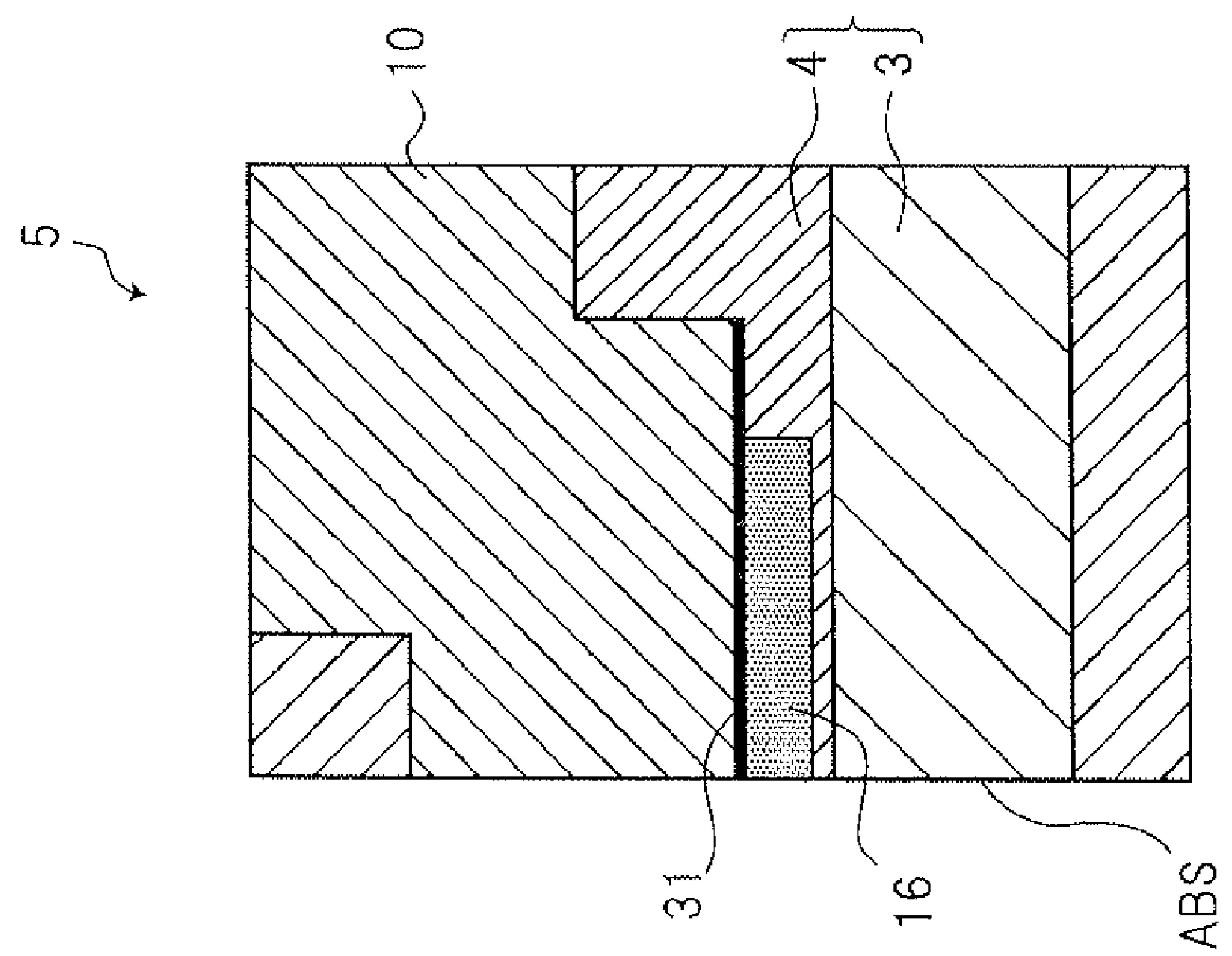


Fig.3

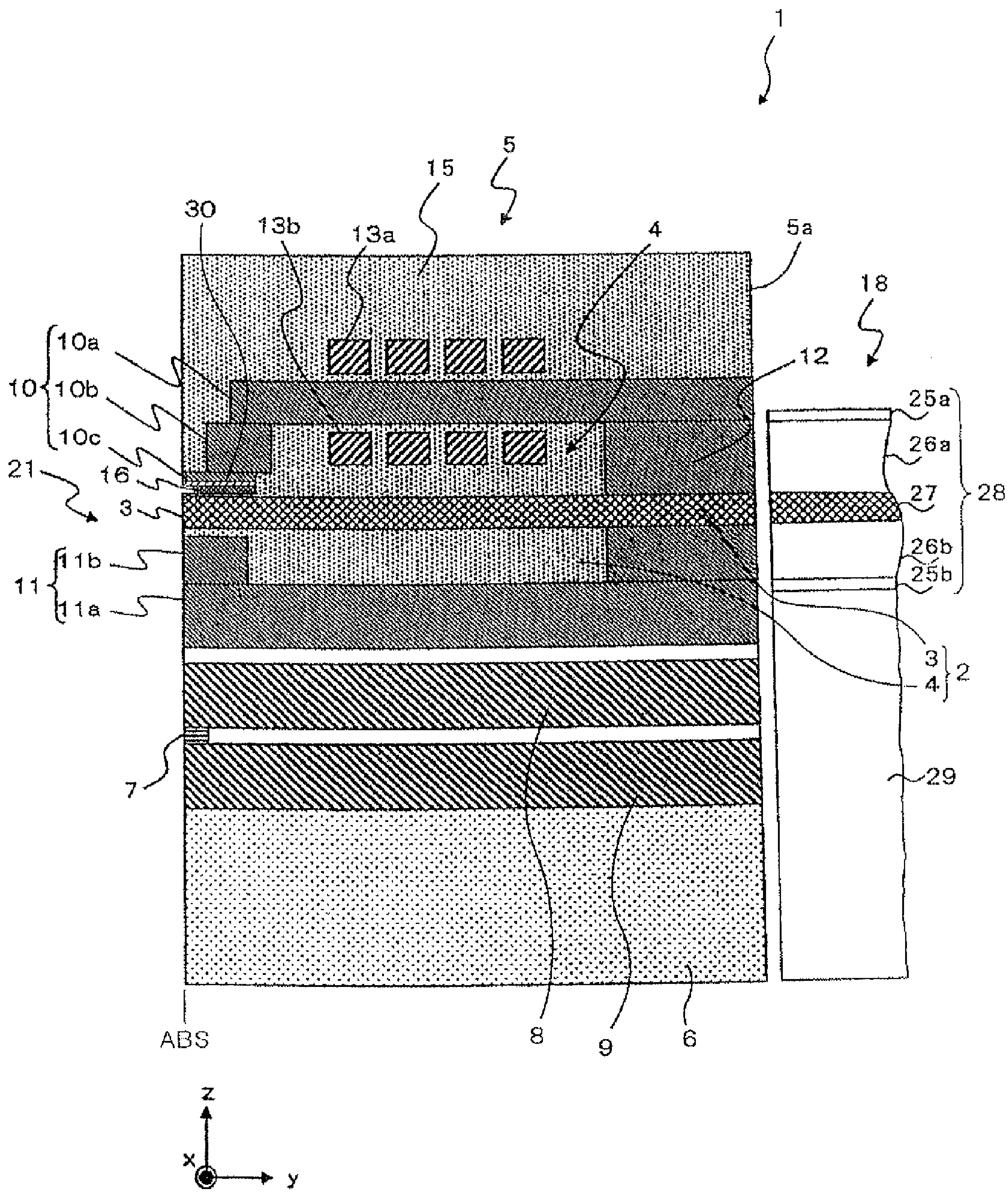

1
5
15
30
13b
13a
4
5a
18
10
10a
10b
10c
12
25a
26a
27
28
21
16
3
26b
25b
11
11b
11a
3
4
2
7
29
ABS
8
9
6
z
x
y

Fig.4

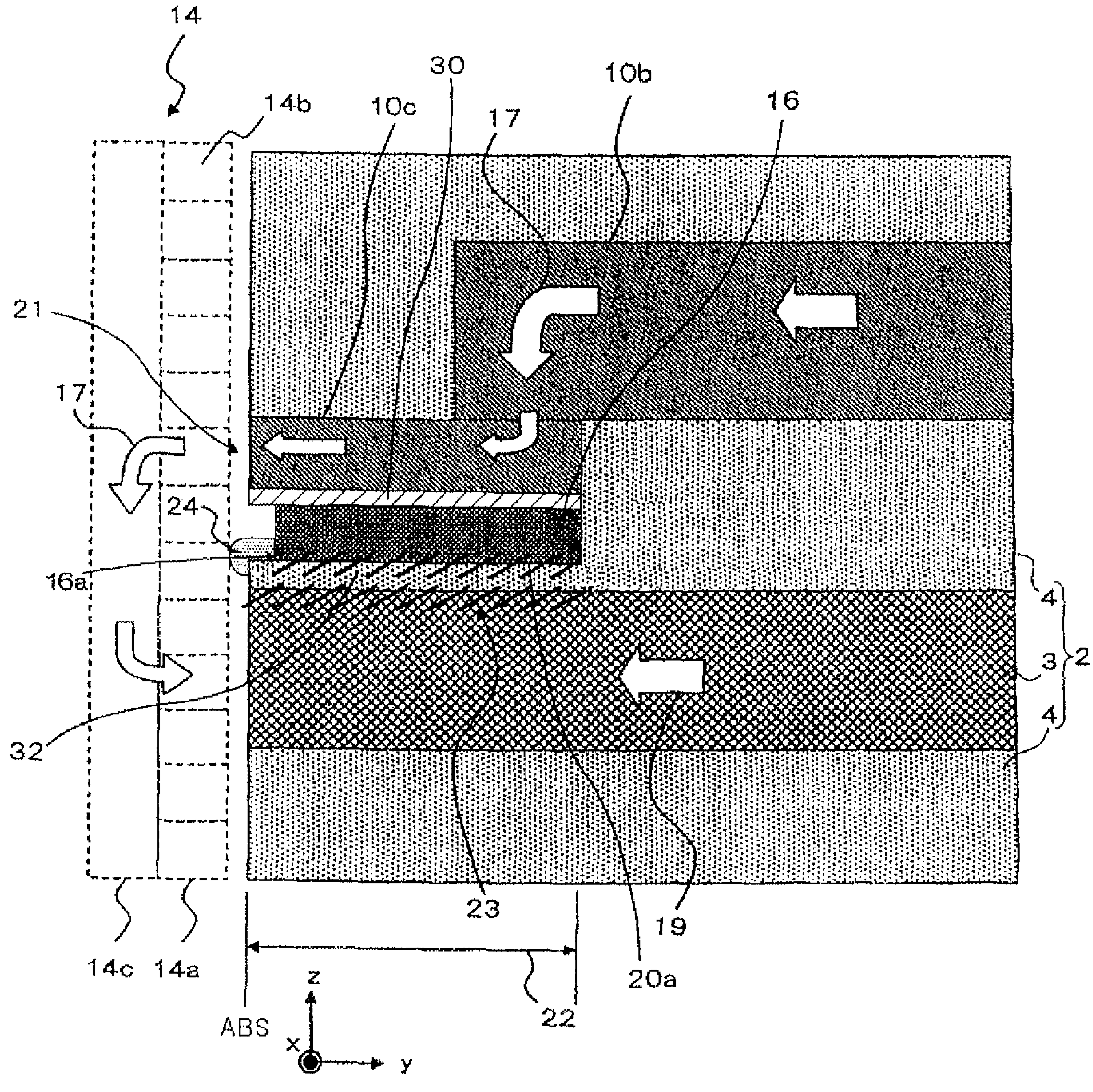

14
14b
10c
30
10b
17
16
21
17
24
16a
4
3
2
4
32
23
19
20a
14c
14a
ABS
22
z
x
y

Fig.5

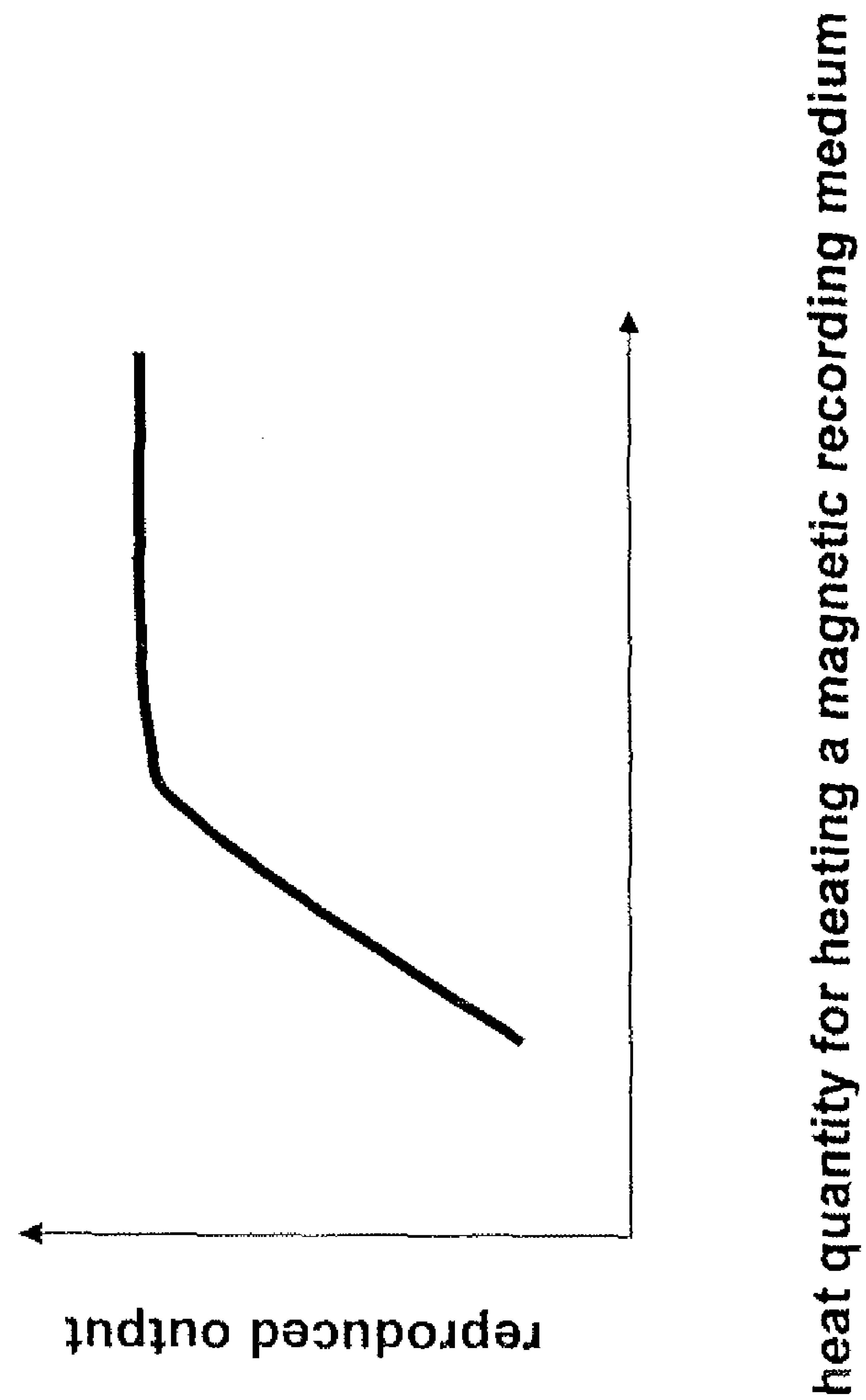

heat quantity for heating a magnetic recording medium
reproduced output

Fig.6

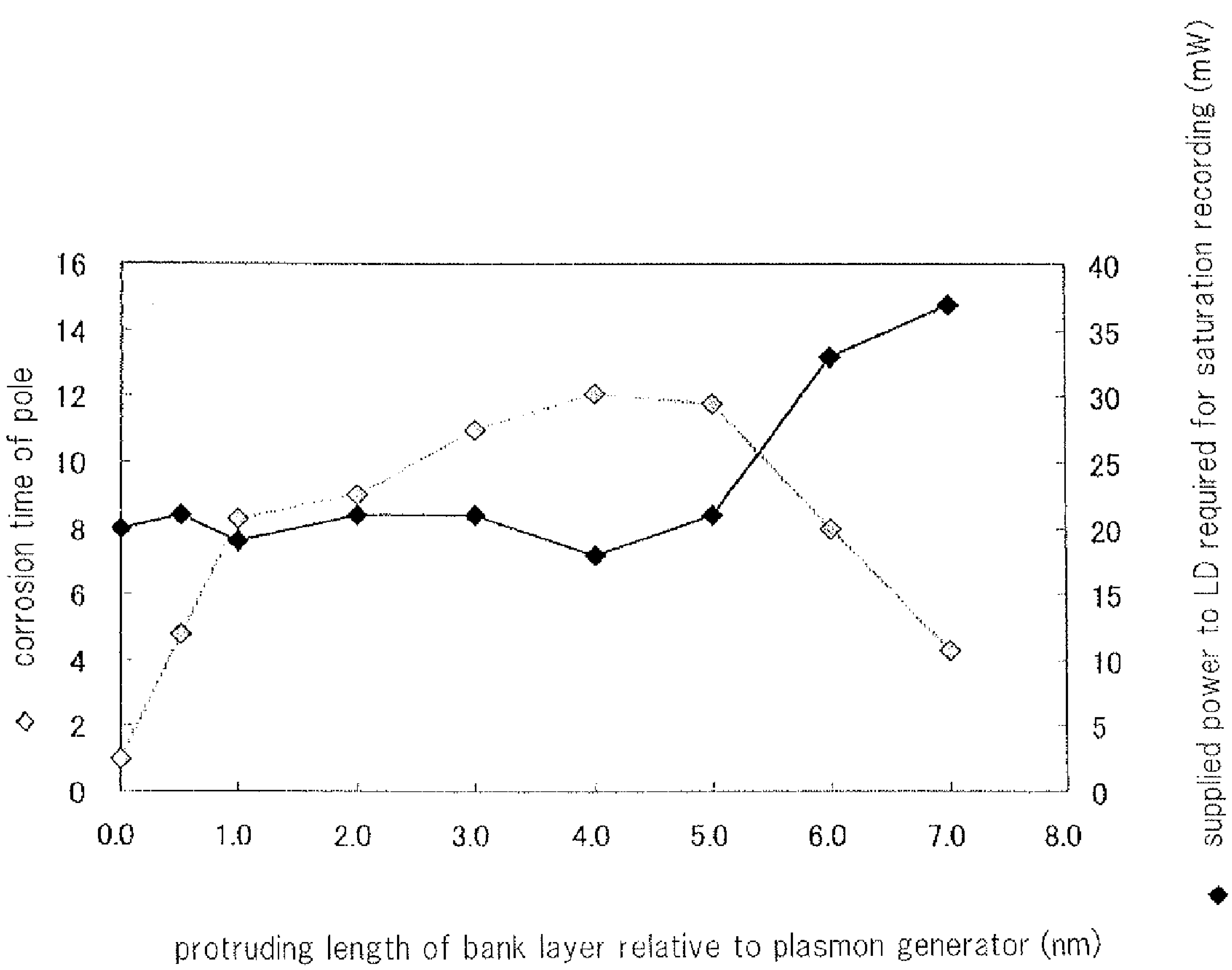

16
14
12
10
8
6
4
2
0
◇ corrosion time of pole
40
35
30
25
20
15
10
5
0
supplied power to LD required for saturation recording (mW) ◆
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
protruding length of bank layer relative to plasmon generator (nm)

Fig.7

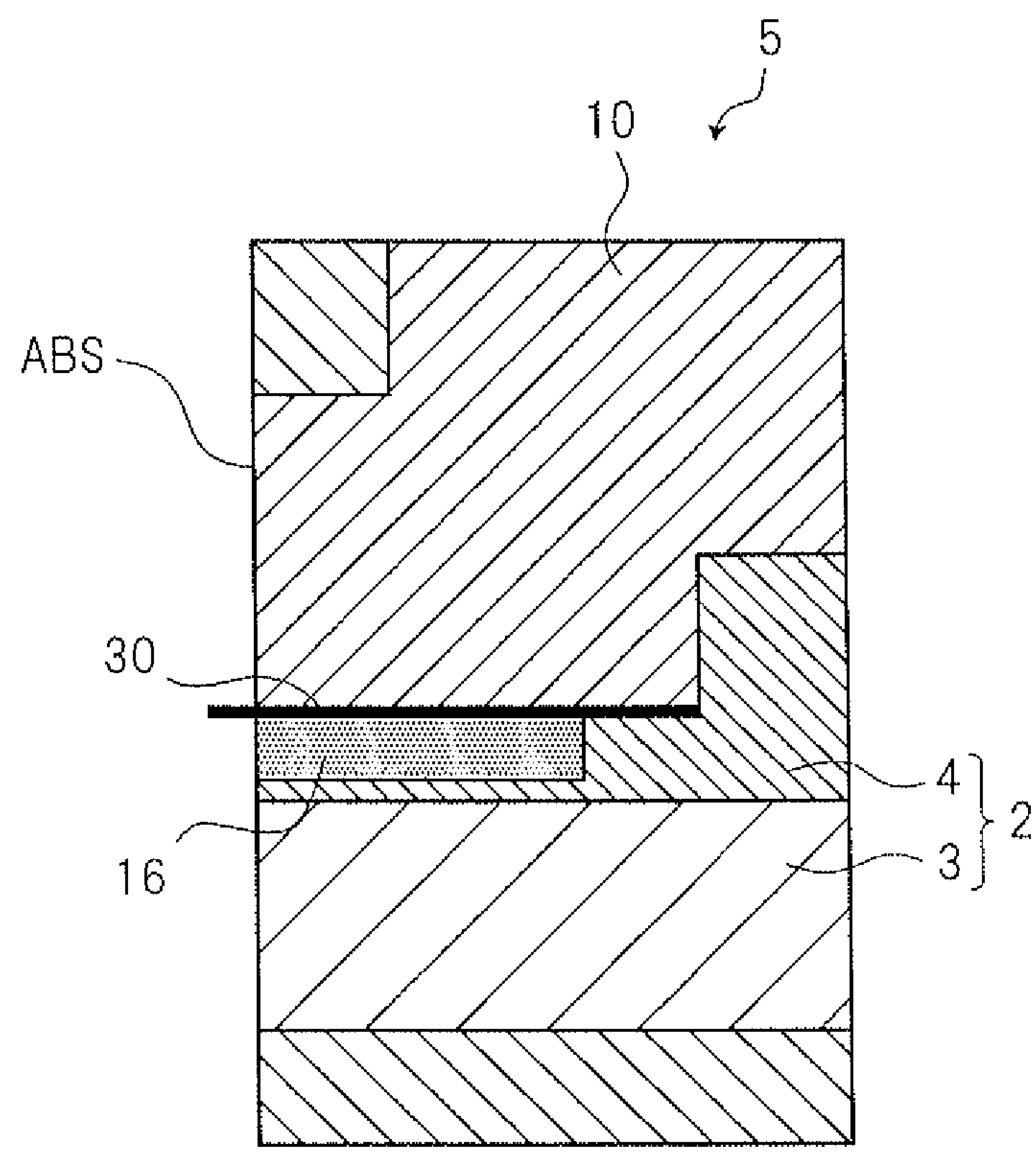


Fig.8

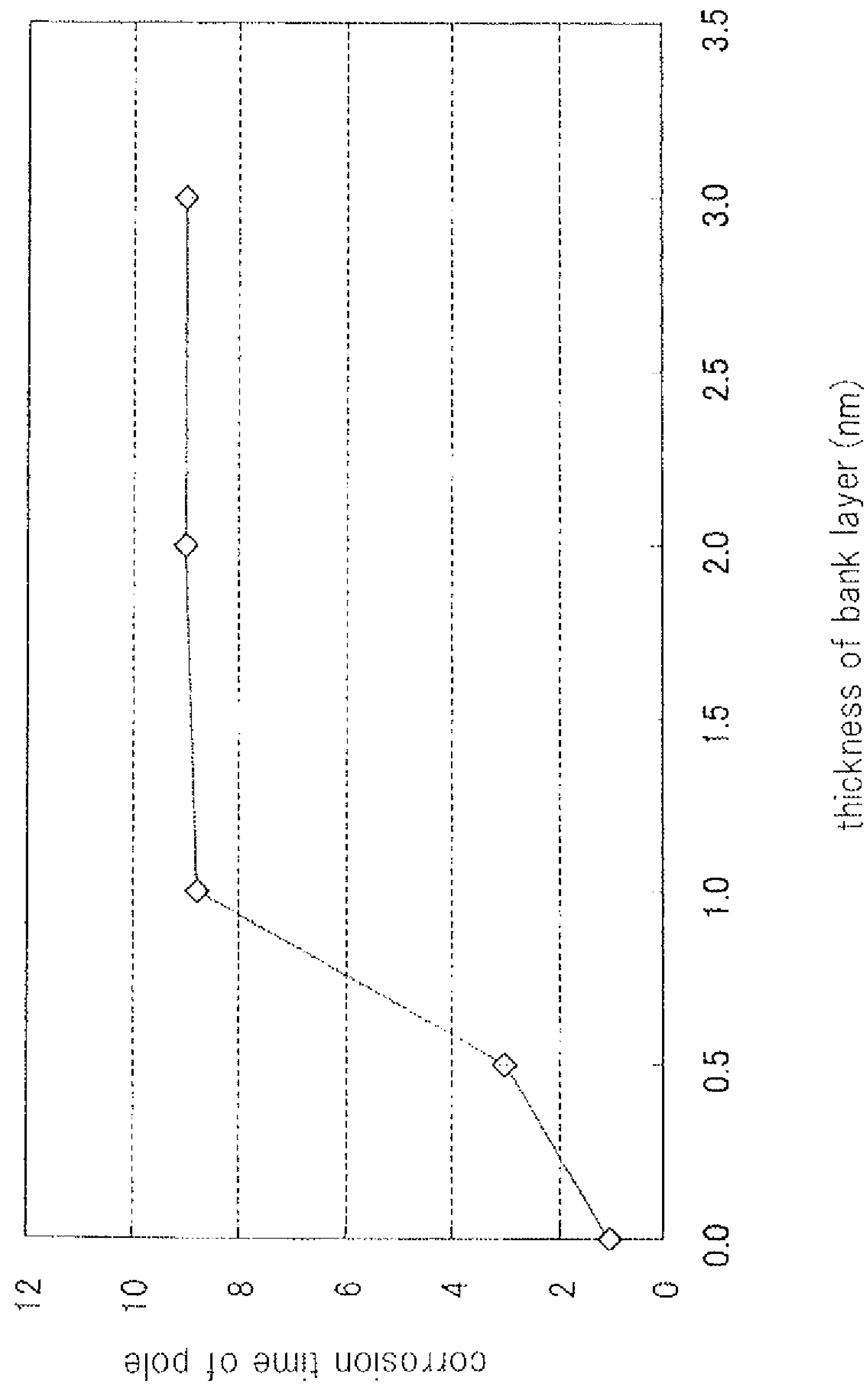

corrosion time of pole
0
2
4
6
8
10
12
thickness of bank layer (nm)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Fig.9

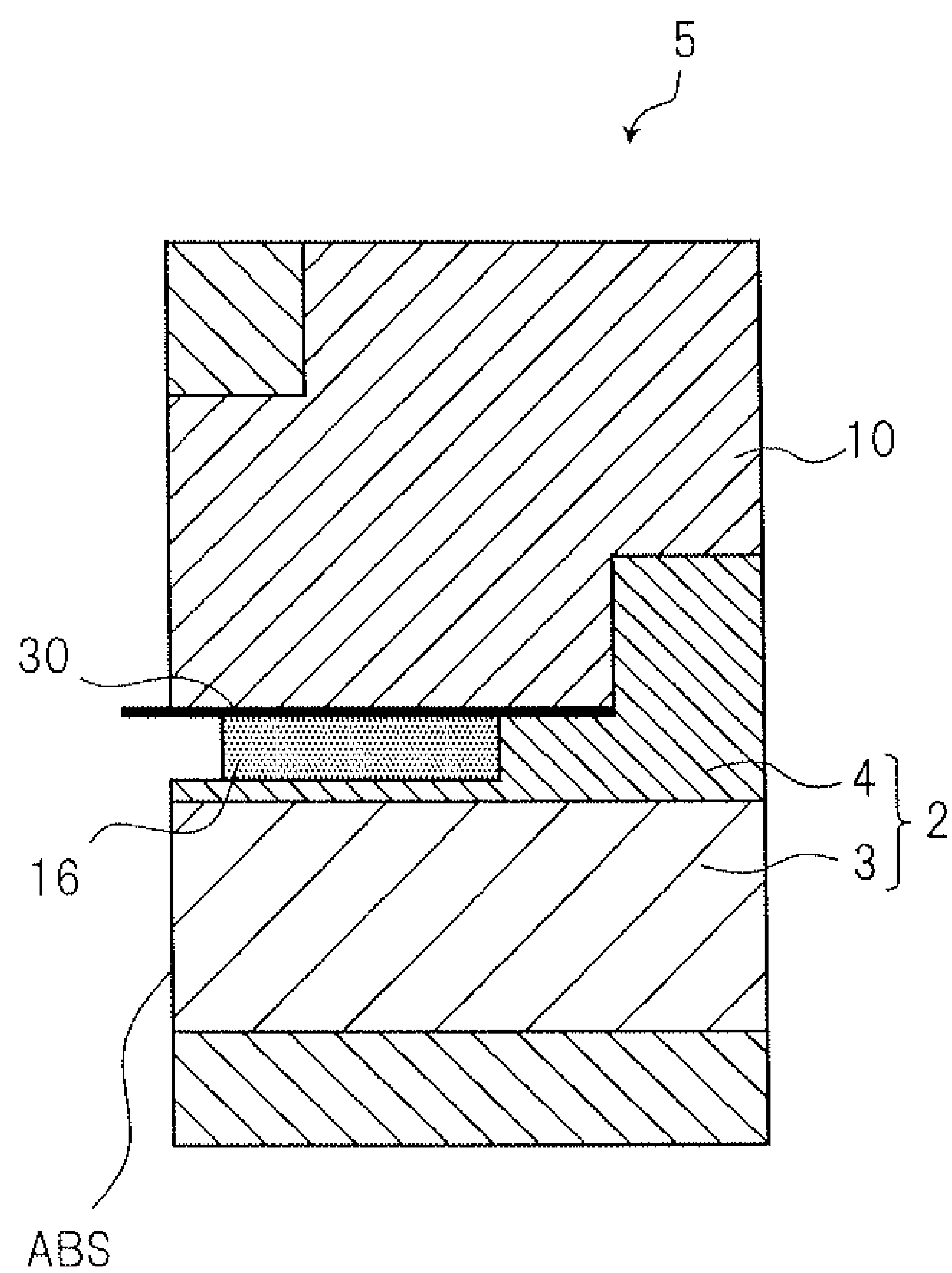


Fig. 10

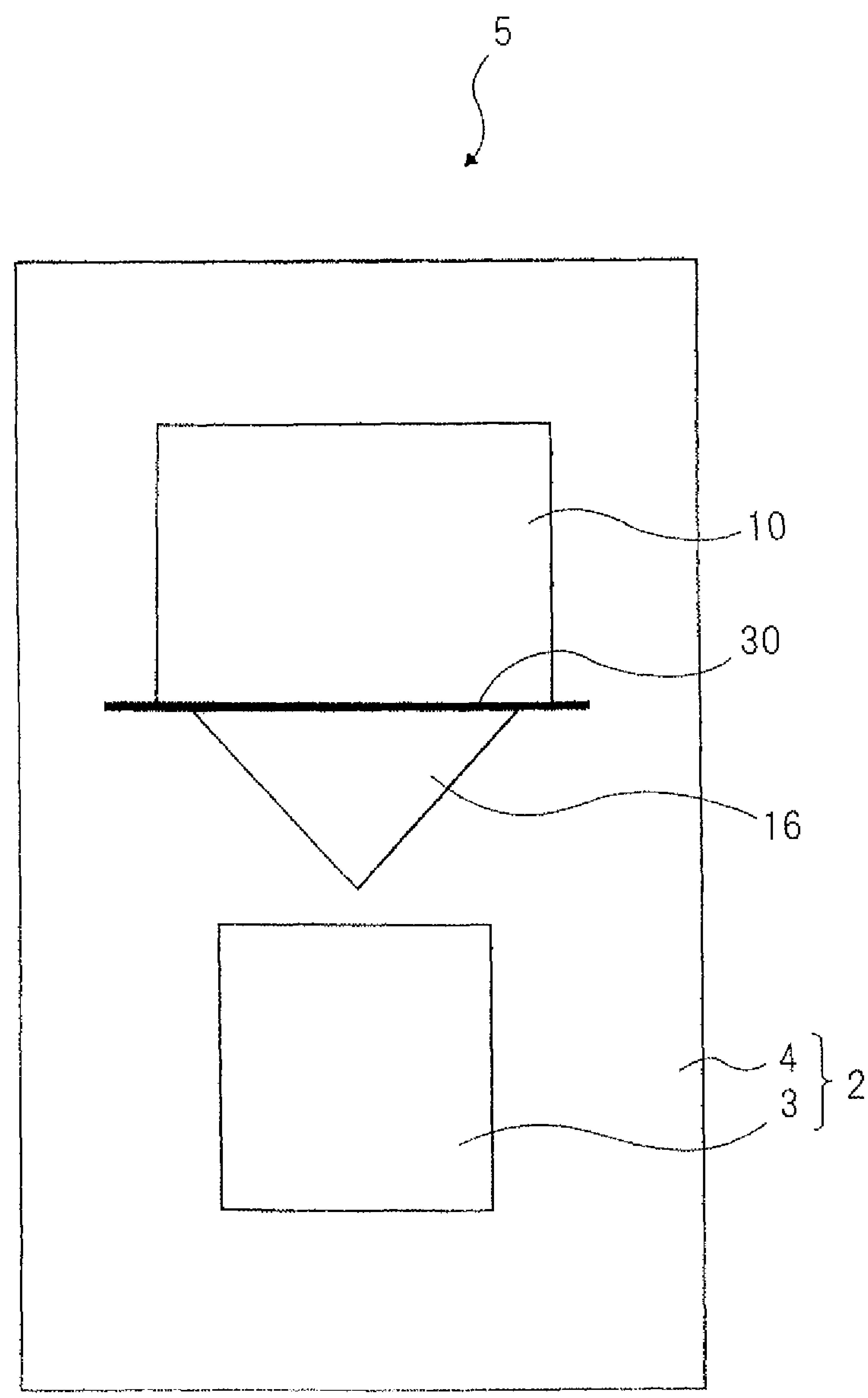


Fig.11

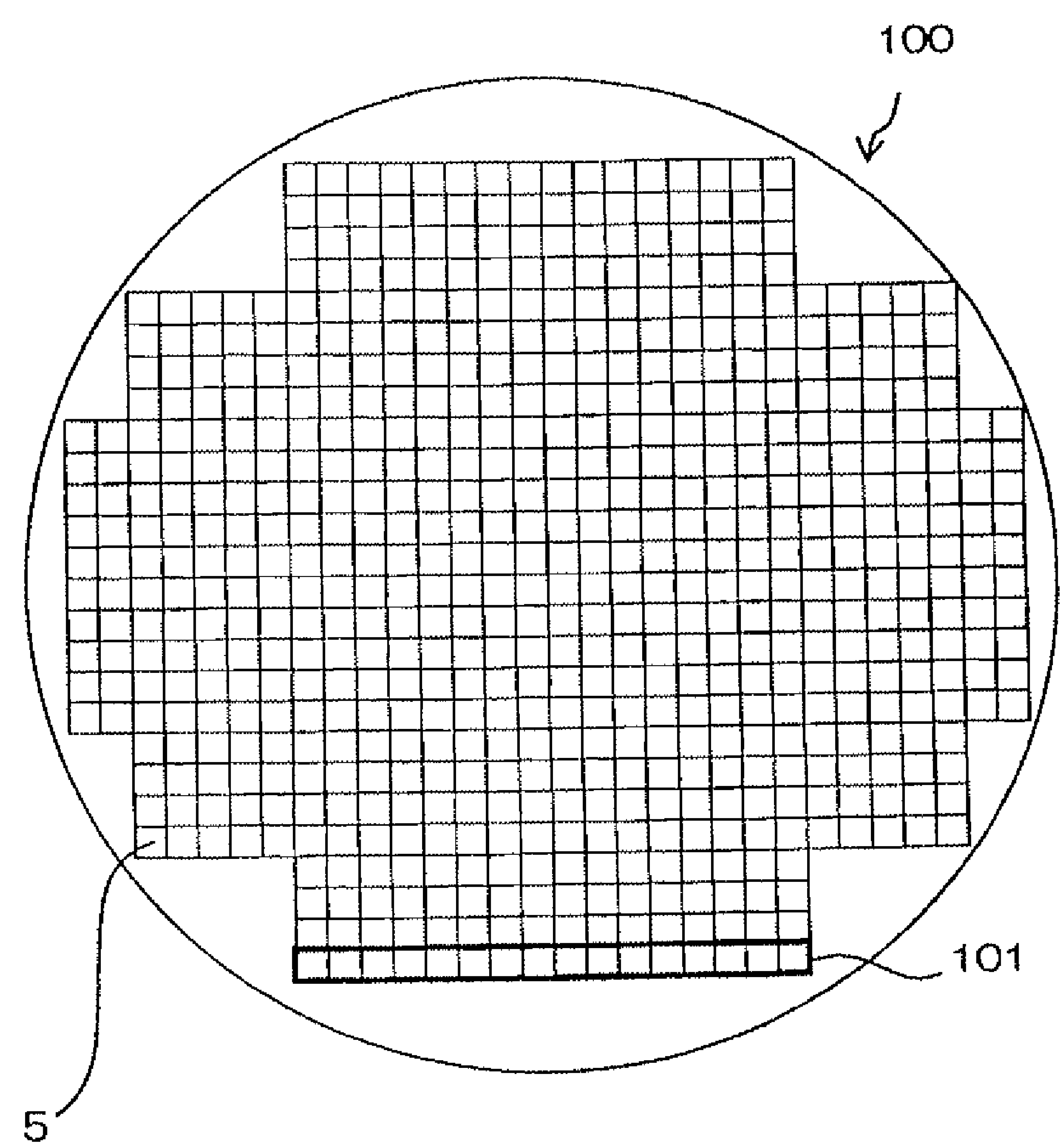


Fig.12

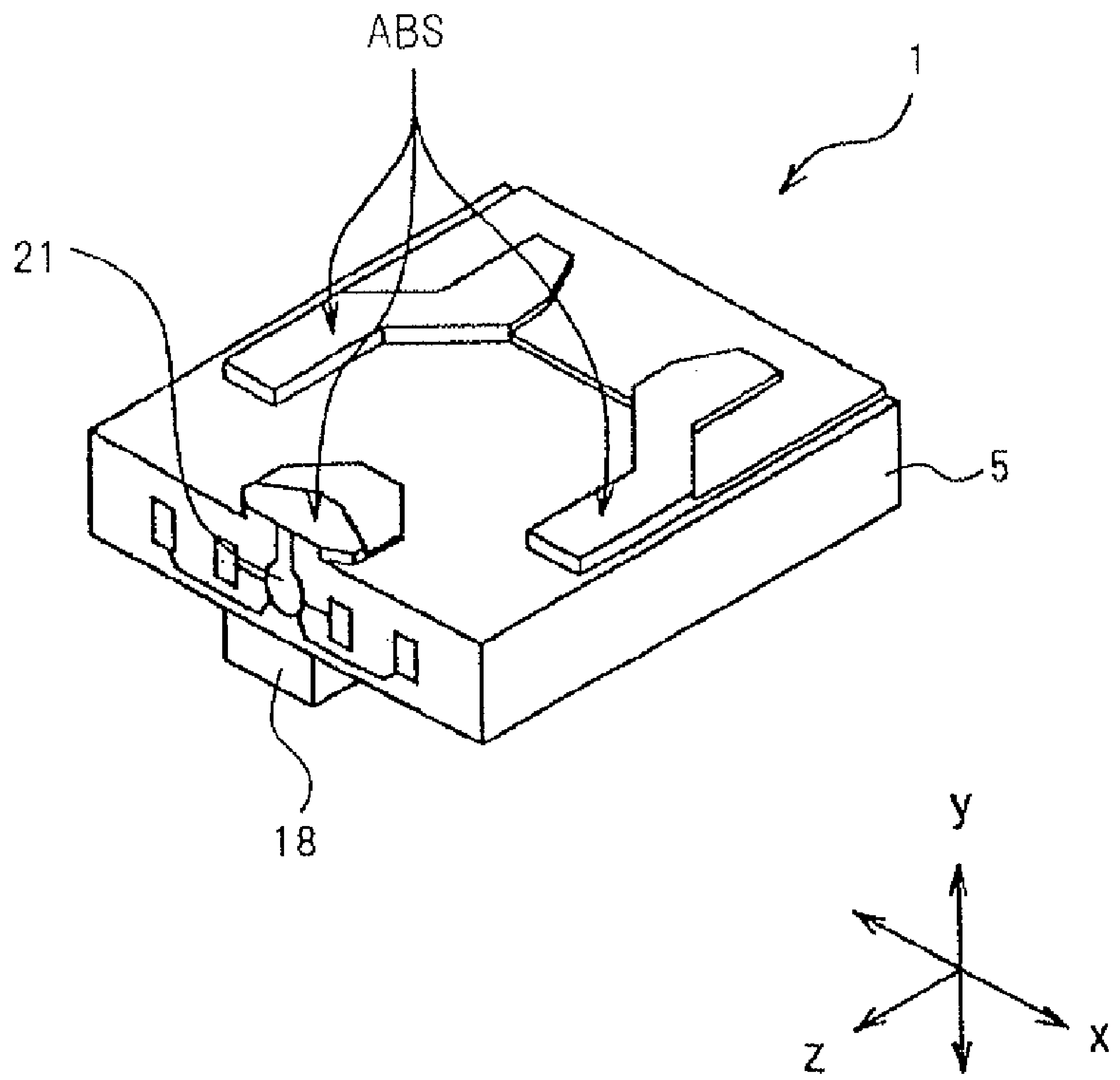


Fig.13

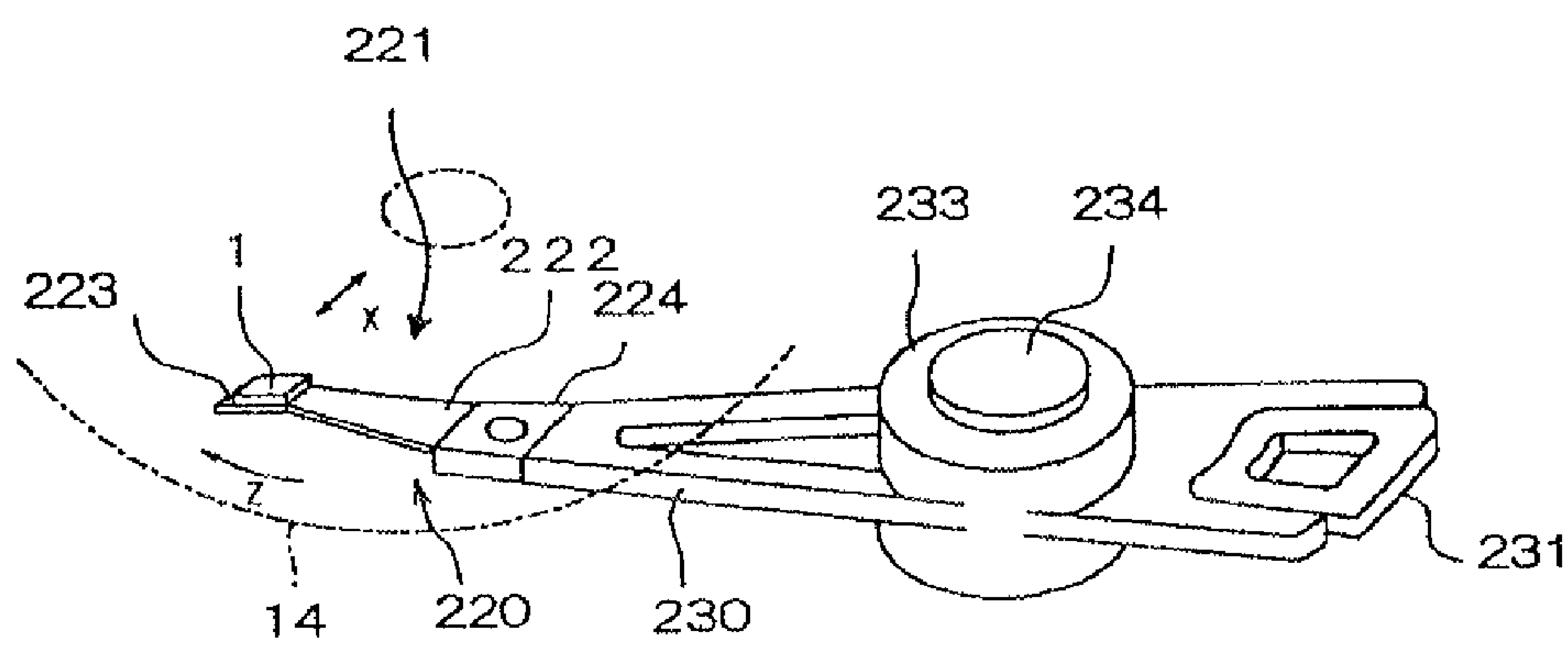


Fig.14

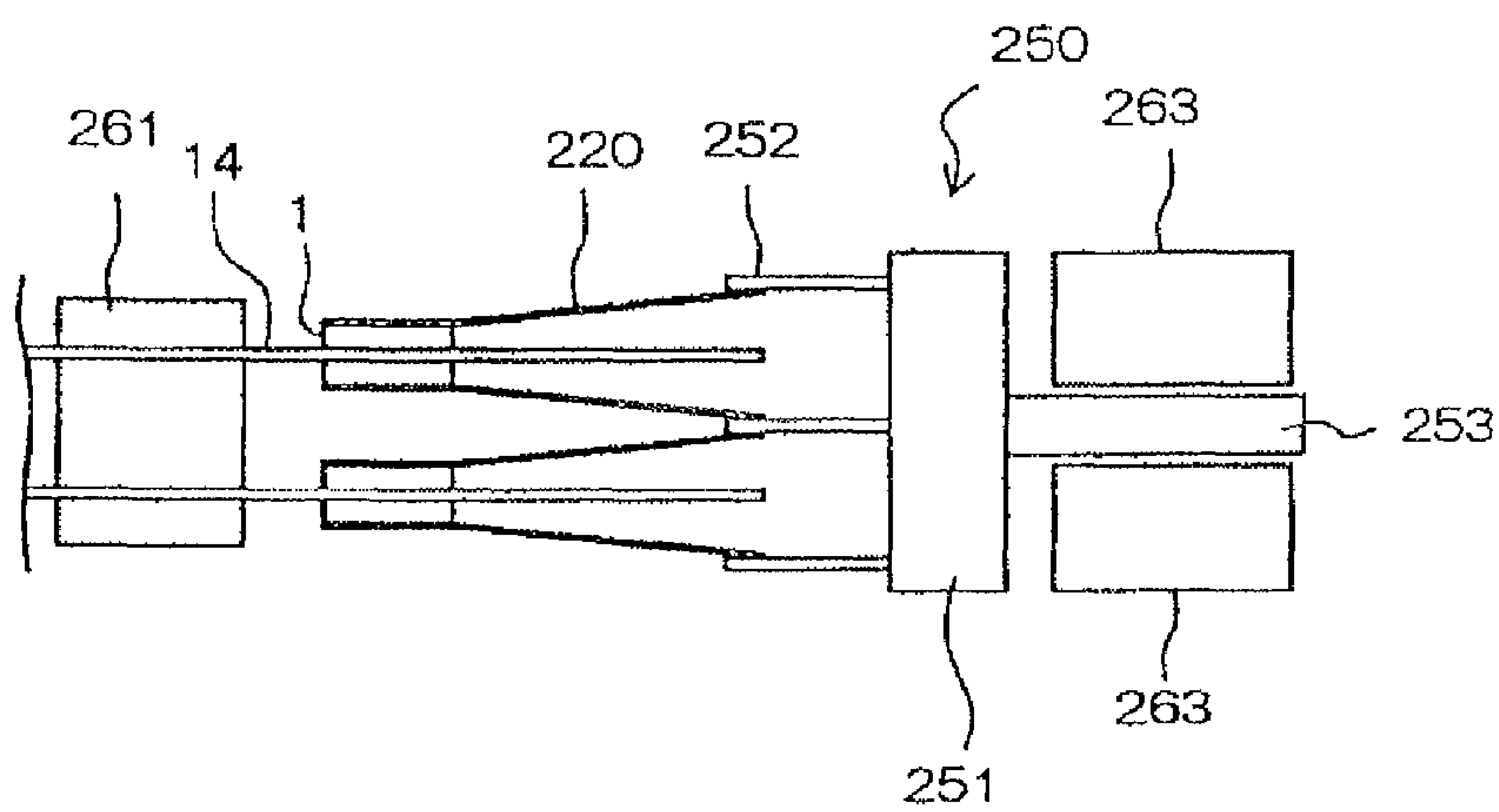
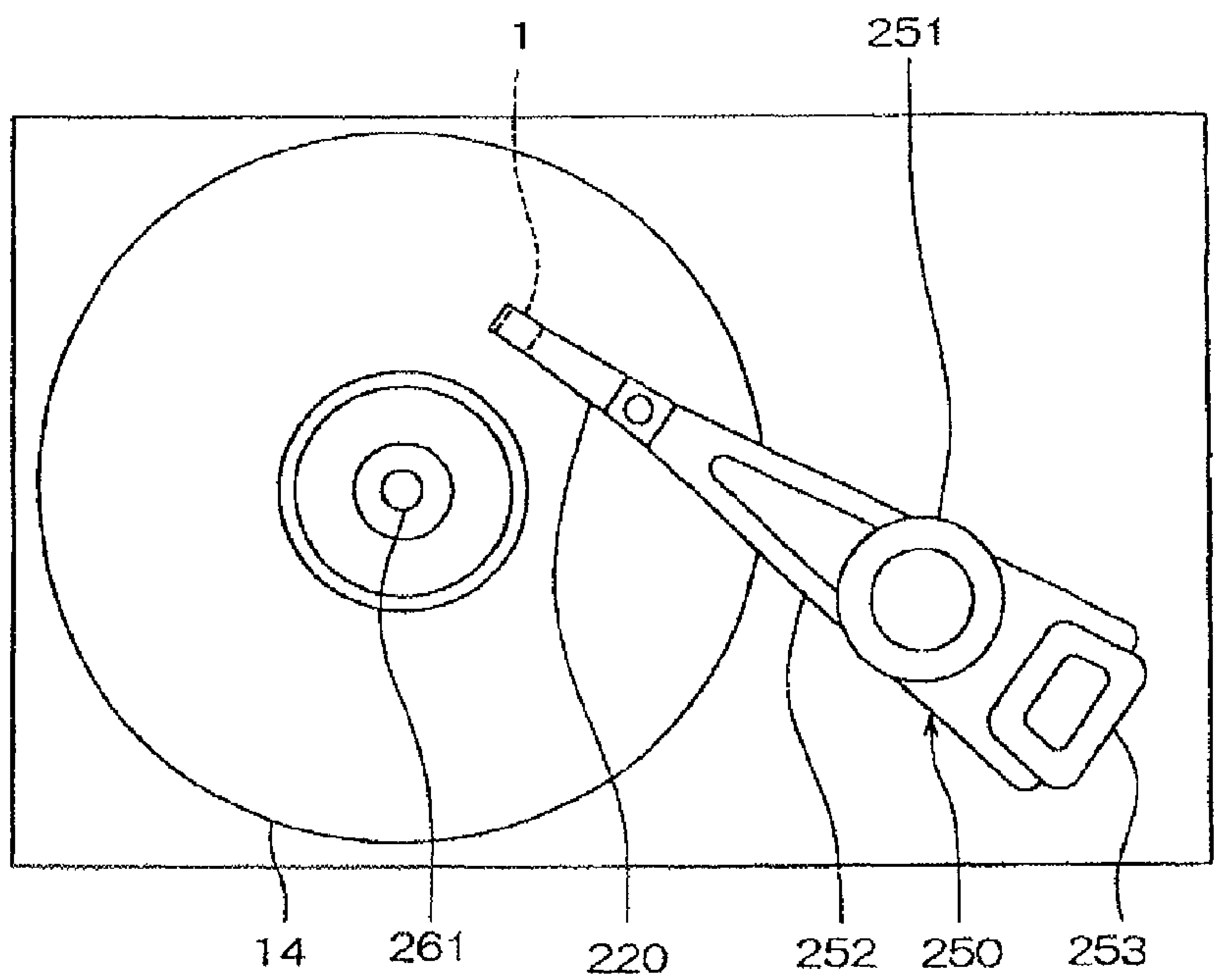


Fig.15



THERMALLY-ASSISTED MAGNETIC HEAD HAVING BANK LAYER BETWEEN MAGNETIC POLE AND PLASMON GENERATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a thermally-assisted magnetic head that records information while heating a magnetic recording medium to reduce coercive force of the magnetic recording medium.

2. Description of the Related Art

In recent years, for magnetic recording devices such as magnetic disk devices, etc., performance improvements of a magnetic head and a magnetic recording medium are demanded in accordance with high recording density. As the magnetic head, a composite-type magnetic head is widely used in which a reproducing head that has a magneto resistive effect element (MR element) for reading and a magnetic recording head that has an inductive-type electromagnetic transducer (a magnetic recording element) for writing are laminated on a substrate. In the magnetic disk devices, the magnetic head flies slightly above a surface of the magnetic recording medium.

The magnetic recording medium is a discontinuous medium on which magnetic microparticles gather. Each of the magnetic microparticles has a single magnetic domain structure. Of the magnetic recording medium, one recording bit is configured with a plurality of the magnetic microparticles. In order to increase the recording density, the asperity of a boundary of adjacent recording bits needs to be small. For this, the size of the magnetic microparticles needs to be small. However, when the size of the magnetic microparticles is small, thermal stability of the magnetization of the magnetic microparticles is also decreased due to the decrease in the volume of the magnetic microparticles. In order to solve this problem, increasing the anisotropy energy of the magnetic microparticles is effective. However, when the anisotropy energy of the magnetic microparticles is increased, the coercive force of the magnetic recording medium is also increased. As a result, it becomes difficult to record information using a conventional magnetic recording head. The conventional magnetic recording head has such a drawback, and this is a large obstacle to achieving an increase in the recording density.

As a method to solve this problem, a so-called thermally-assisted magnetic recording method has been proposed. In this method, a magnetic recording medium that has large coercive force is utilized. The magnetic field and heat are simultaneously applied to a portion of the magnetic recording medium to which information is recorded at the time of recording the information. Using this method, the information is recorded under a state where the temperature is increased and the coercive force is decreased in the information recording portion.

For thermally-assisted magnetic recording, a method in which a laser light source is utilized to heat the magnetic recording medium is common. Such a method has two types of methods: one method is to heat the magnetic recording medium by guiding laser light to a recording portion via a waveguide, etc. (a direct heating type); and the other method is to heat the magnetic recording medium by converting laser light to near-field light (a near-field light heating type). Near-field light is a type of electromagnetic field that is formed around a substance. Ordinary light cannot be tapered to a smaller region than its wavelength due to diffraction limitations. However, when light having an identical wavelength is irradiated onto a microstructure, near-field light that depends on the scale of the microstructure is generated, enabling the light to be tapered to a minimal region being approximately tens of nm in size. Since the thermally-assisted recording targets recording density region that requires selective heating only to the minimal region being approximately tens of nm, the near-field light heating type is preferred.

In U.S. Patent Application Publication No. 2008/205202, a configuration is disclosed in which a near-field-generator is disposed in a front part of a core of a waveguide through which light from a laser diode (LD) propagates.

As a concrete method for generating the near-field light, a method using a so-called plasmon antenna, which is a metal referred to as a near-field light probe that generates near-field light from light-excited plasmon, is common.

Direct irradiation of light generates the near-field light in the plasmon antenna; however, conversion efficiency of converting irradiated light into the near-field light is low with this method. Most of the energy of the light irradiated on the plasmon antenna reflects off the surface of the plasmon antenna or is converted into thermal energy. The size of the plasmon antenna is set to the wavelength of the light or less, so that the volume of the plasmon antenna is small. Accordingly, the temperature increase in the plasmon antenna due to that the light energy is converted into the thermal energy is significantly large.

The temperature increase causes volume expansion of the plasmon antenna, and the plasmon antenna protrudes from an air bearing surface (ABS) that is a surface facing the magnetic recording medium. Then, the distance between an edge part of the MR element on the ABS and the magnetic recording medium increases, causing a problem that servo signals recorded on the magnetic recording medium cannot be read during the recording process. Moreover, when the heat generation is large, the plasmon antenna may melt.

Currently, a technology is proposed in which light is not directly irradiated onto the plasmon antenna. For example, U.S. Pat. No. 7,330,404 discloses such a technology. In this technology, light propagating through a waveguide such as an optical fiber, etc. is not directly irradiated onto the plasmon antenna; however the light is coupled with a plasmon generator in a surface plasmon mode via a buffer portion to excite a surface plasmon in the plasmon generator. The plasmon generator includes a near-field-generator that is positioned on the ABS and that generates the near-field light. At the interface between the waveguide and the buffer portion, the light propagating through the waveguide completely reflects off, and light, which is referred to as evanescent light, is simultaneously generated that penetrates into the buffer portion. The evanescent light and a collective oscillation of charges in the plasmon generator are coupled, and the surface plasmon is then excited in the plasmon generator. The excited surface plasmon propagates to the near-field-generator along the plasmon generator, and then generates near-field light in the near-field-generator. According to this technology, since the light propagating through the waveguide is not directly irradiated to the plasmon generator, an excessive temperature increase of the plasmon generator is prevented.

U.S. Patent Application Publication No. 2010/103553 discloses a configuration in which a propagation edge is disposed in a plasmon generator that couples to light in a surface plasmon mode. The propagation edge that is an extremely narrow region is for propagating a surface plasmon generated in a plasmon generator to a near-field-generator positioned on an ABS.

In the thermally-assisted magnetic head that generates near-field light using evanescent light, a distance between a pole of an inductive-type electromagnetic transducer (magnetic recording element) for writing and a plasmon generator should be reduced to the extent possible to achieve high recording density. To achieve this, a configuration may be considered in which a dielectric body layer does not exist between the pole and the plasmon generator. However, with such a configuration, corrosion (oxidation) of the pole occurs due to contact and an electrical short between the pole and the plasmon generator. The pole loses its properties as a magnetic material when the pole is corroded, and thus the function of the magnetic recording element deteriorates.

U.S. Pat. No. 7,262,940 discloses a configuration in which an insulation film is disposed between a reproducing element and a recording element to separate them in order to suppress thermal deformation of the reproducing element in a magnetic head without thermal-assistance function. Similarly, JP Patent Application Publication No. H5-28430 discloses a configuration in which a pole is disposed in a recessed position relative to an alumina protecting film from an ABS in order to prevent a magnetic head from contacting the magnetic recording medium due to heat expansion of a pole of a magnetic recording element. U.S. Pat. No. 6,470,565 discloses a configuration in which a recession length (gap) of a magnetic head from other parts of a slider on an ABS is reduced. Since these magnetic heads are not configured for thermally-assisted magnetic recording, these configurations are not directed to suppress corrosion of the pole due to the contact of the plasmon generator and the pole of the magnetic recording element.

U.S. Patent Application Publication No. 2009/073597 discloses a configuration in which a heat dissipation film made of a material having a large thermal conductivity is disposed in the vicinity of a pole of a recording element. Additionally, the heat dissipation film is neither for preventing contact of the pole and a plasmon generator nor for preventing corrosion of the pole.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a thermally-assisted magnetic head that can suppress corrosion of a pole due to contact of a plasmon generator and the pole of a magnetic recording element.

A thermally-assisted magnetic head that has an ABS facing a recording medium and that performs magnetic recording while heating the recording medium includes: a magnetic recording element that includes a pole of which an edge part is positioned on the ABS and which generates magnetic flux traveling to the recording medium; a waveguide that is configured with a core through which light propagates and a cladding, surrounding a periphery of the core, at least one part of which extends to the ABS; a plasmon generator that faces a part of the core and that extends toward the ABS side; and a bank layer that is positioned between the plasmon generator and the pole, and of which an edge part on the ABS side protrudes relative to the plasmon generator.

With the configuration, even when the plasmon generator is expanded, the plasmon generator cannot extend over the bank layer, or contact the pole. Accordingly, a corrosion of the pole is suppressed.

The above and other objects, features and advantages of the present invention will become apparent from the following description with reference to the accompanying drawings which illustrate examples of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a schematic view of an ABS of a thermally-assisted magnetic head of a first embodiment of the present invention;

FIG. **1**B is a schematic cross-sectional view of the thermally-assisted magnetic head illustrated in FIG. **1**A, cut along line A-A of FIG. **1**A;

FIGS. **2**A-**2**C are schematic cross-sectional views for explaining heat expansion of a plasmon generator of the thermally-assisted magnetic head;

FIG. **3** is a cross-sectional view illustrating the details of a main part of the thermally-assisted magnetic head illustrated in FIGS. **1**A and **1**B;

FIG. **4** is an enlarged view of the vicinity of the plasmon generator of the thermally-assisted magnetic head illustrated in FIG. **3**;

FIG. **5** is a graph illustrating a relationship between reproduced output and heat quantity for heating a medium with the thermally-assisted magnetic head;

FIG. **6** is a graph illustrating relationships between protruding length of a bank layer of the thermally-assisted magnetic head illustrated in FIGS. **1**A-**4** relative to the plasmon generator and corrosion time of the pole and supplied power to an LD required for saturation recording;

FIG. **7** is a schematic cross-sectional view of a thermally-assisted magnetic head of a second embodiment of the present invention;

FIG. **8** is a graph illustrating a relationship between a thickness of a bank layer of the thermally-assisted magnetic head illustrated in FIG. **7** and corrosion time of a pole;

FIG. **9** is a schematic cross-sectional view of a thermally-assisted magnetic head of a third embodiment of the present invention;

FIG. **10** is a schematic view illustrating an ABS of a modified example of the thermally-assisted magnetic head of the present invention;

FIG. **11** is a plan view of a wafer where a large number of stacks that configure a slider of the thermally-assisted magnetic head of the present invention are formed;

FIG. **12** is a perspective view of the thermally-assisted magnetic head of the present invention, as seen from an ABS side;

FIG. **13** is a perspective view of a head arm assembly that includes a head gimbal assembly in which the thermally-assisted magnetic head of the present invention is incorporated;

FIG. **14** is a side view of the head arm assembly in which the thermally-assisted magnetic head of the present invention is incorporated; and

FIG. **15** is a plan view of a hard disk device in which the thermally-assisted magnetic head of the present invention is incorporated.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A thermally-assisted magnetic head of the present invention will be explained referring to the drawings.

[First Embodiment]

First, a basic configuration of a thermally-assisted magnetic head of the present invention will be explained. The thermally-assisted magnetic head performs so-called thermally-assisted magnetic recording in which information is recorded by application of a magnetic field when coercive force is partially reduced by heating a magnetic recording medium.

However, corrosion (oxidation) of the pole occurs with such a configuration. It is considered that the main reason why the corrosion of the pole occurs may be a difference of electrode potential, which is generated due to a direct contact between a magnetic element (for example, Fe, Co, Ni) which is a base metal and a material (for example Au, Ag, Cu or the like) which is a noble metal and which configures the plasmon generator **16**. Table 1 illustrates standard electrode potential of representative metals.

TABLE 1

$Li^+ + e^- \Leftrightarrow Li$	−3.040	$Ti^{2+} + 2e^- \Leftrightarrow Ti$	−1.630	$Pb^{2+} + 2e^- \Leftrightarrow Pb$	−0.126
$K^+ + e^- \Leftrightarrow K$	−2.925	$Zr^{4+} + 4e^- \Leftrightarrow Zr$	−1.550	$2H^+ + 2e^- \Leftrightarrow H_2$	0.000
$Rb^+ + e^- \Leftrightarrow Rb$	−2.924	$Mn^{2+} + 2e^- \Leftrightarrow Mn$	−1.180	$Cu^{2+} + 2e^- \Leftrightarrow Cu$	0.337
$Ba^{2+} + 2e^- \Leftrightarrow Ba$	−2.920	$Zn^{2+} + 2e^- \Leftrightarrow Zn$	−0.763	$Cu^+ + e^- \Leftrightarrow Cu$	0.520
$Sr^{2+} + 2e^- \Leftrightarrow Sr$	−2.890	$Cr^{3+} + 3e^- \Leftrightarrow Cr$	−0.740	${Hg_2}^{2+} + 2e^- \Leftrightarrow 2Hg$	0.796
$Ca^{2+} + 2e^- \Leftrightarrow Ca$	−2.840	$Fe^{2+} + 2e^- \Leftrightarrow Fe$	−0.440	$Ag^+ + e^- \Leftrightarrow Ag$	0.799
$Na^+ + e^- \Leftrightarrow Na$	−2.714	$Cd^{2+} + 2e^- \Leftrightarrow Cd$	−0.403	$Hg^{2+} + 2e^- \Leftrightarrow Hg$	0.850
$Mg^{2+} + 2e^- \Leftrightarrow Mg$	−2.356	$Co^{2+} + 2e^- \Leftrightarrow Co$	−0.277	$Pt^{2+} + 2e^- \Leftrightarrow Pt$	1.188
$Al^{3+} + 3e^- \Leftrightarrow Al$	−1.676	$Ni^{2+} + 2e^- \Leftrightarrow Ni$	−0.257	$Au^{3+} + 3e^- \Leftrightarrow Au$	1.520
$U^{3+} + 3e^- \Leftrightarrow U$	−1.660	$Sn^{2+} + 2e^- \Leftrightarrow Sn$	−0.138	$Au^+ + e^- \Leftrightarrow Au$	1.830

As illustrated schematically in FIGS. **1**A and **1**B, a slider **5** of a thermally-assisted magnetic head **1** includes a magnetic recording element **21** and a waveguide **2**. The magnetic recording element **21** configures a recording head part, and the waveguide **2** into which laser light used for heating the magnetic recording medium enters. The waveguide **2** is configured with a core **3** and a cladding **4** surrounding the periphery of the core **3**. In the slider **5** of the thermally-assisted magnetic head **1**, a plasmon generator **16** couples to propagation light entering into and propagating through the core **3** in a surface plasmon mode, and a surface plasmon is generated. The generated surface plasmon propagates toward an ABS, and near-field light is generated at a near-field-generator positioned at an edge part of the plasmon generator **16** on the ABS side. While the magnetic recording medium is locally heated by the near-field light converted from the laser light as described above, magnetic flux that travels to the magnetic recording medium is generated in a pole **10** of the magnetic recording element **21**, and thereby magnetic information is recorded. A bank layer **30** made of an insulator is disposed between the pole **10** of the magnetic recording element **21** and the plasmon generator **16** through which the laser light propagates in the thermally-assisted magnetic head **1** of the present invention. The bank layer **30** protrudes toward the magnetic recording medium side relative to the plasmon generator **16** on the ABS. As illustrated in FIGS. **1**A and **1**B, the bank layer **30** relatively protrudes because the plasmon generator **16** is recessed from the ABS in the present embodiment. A protruding length of the bank layer **30** relative to the plasmon generator **16** (recession length of the plasmon generator **16**) is from 0 nm (exclusive) to 5 nm (inclusive), and a thickness thereof is 1 nm or less.

The technical significance of the bank layer **30** will be explained. In the thermally-assisted magnetic head **1**, magnetic information is written by simultaneously applying heat and magnetic flux to the same portion of the magnetic recording medium. Therefore, when the plasmon generator **16** and the pole **10** of the magnetic recording element **21** are disposed closely to the extent possible, this provides high space efficiency and moreover contributes to realize high recording density. The plasmon generator **16** is for heating, and the near-field-generator is disposed at the edge part of the plasmon generator **16** on the ABS side. In order to achieve this, a configuration is considered in which a dielectric body layer is not disposed between the pole and the plasmon generator.

In addition, the standard electrode potential is a value of electrode potential at a standard state (25° C., 1 atm) based on electrode potential (1.0) of standard hydrogen electrode (SHE). Usually, when two or more metals are joined, the metal having a small standard electrode potential (base metal) is corroded prior to the metal having a large standard electrode potential (noble metal).

In order to electrically separate two or more of the metals and prevent corrosion, an insulation layer may be disposed between the metals. However, it is desired to reduce a distance between the pole **10** and the plasmon generator **16** to the extent possible in the thermally-assisted magnetic head in order to achieve high recording density as described above. One of the configurations in which the distance between the pole **10** and the plasmon generator **16** is reduced is a configuration in which the plasmon generator **16** is a V-shaped plasmon generator that protrudes toward the core **3** on the ABS, and the pole **10** has a reverse-triangle shaped portion along the plasmon generator **16** on at least a portion on the plasmon generator **16** side on the ABS (see FIG. **1**A).

As illustrated in FIG. **2**A, in a configuration in which a thin insulation layer **31** (may be made of the same material as the cladding **4** as one example) is disposed between the pole **10** and the plasmon generator **16**, the plasmon generator **16**, which faces the core **3** into which laser light enters, selectively protrudes due to heat expansion (see FIG. **2**B), extends over the insulation layer **31** on the ABS and goes around, and contacts the pole **10**, which may cause an electrical short (see FIG. **2**C). As a result, corrosion of the pole **10** occurs, resulting in a decrease in output of the thermally-assisted magnetic head.

In the present invention, the bank layer **30** is disposed between the plasmon generator **16** and the pole **10**, and the bank layer **30** protrudes toward the ABS side relative to the plasmon generator **16**. Even when heat expansion of the plasmon generator **16**, which contributes to the generation of near-field light and itself is likely to be heated, occurs, the heat-expanded plasmon generator does not extend over the bank layer **30** on the ABS, so that there is no possibility that it contacts the pole **10**. Accordingly, as well as contact and an electrical short between the pole **10** and the plasmon generator **16** is prevented, and the corrosion of the pole **10** is suppressed, the configuration contributes to realizing high recording density since the bank layer **30** is relatively thinned.

Further detailed description of the above-described thermally-assisted magnetic recording head **1** of the present embodiment will be provided. FIG. **3** is a cross-sectional view illustrating a main part of the thermally-assisted magnetic head **1** illustrated in FIG. **1** in detail. FIG. **4** is an enlarged view of a part of the slider **5**. As illustrated in FIG. **3**, the slider **5** has a configuration in which an MR element **7** that configures a reproducing head part and a magnetic recording element **21** that is a recording head part are layered on a substrate **6** made of ALTIC (Al_2O_3.TiC). In the following description, a "lamination direction" indicates a film formation direction and a direction orthogonal to a film surface in a wafer formation process, and corresponds to the z-direction in each of the drawings. An "upper in the lamination direction" refers to a direction oriented toward an overcoat layer **15** from the substrate **6**. A "lower in the lamination direction" refers to a direction oriented toward the substrate **6** from the overcoat layer **15**.

The slider **5** includes, as the reproducing head part, the MR element **7** that has an end exposed on the ABS, and an upper shield layer **8** and a lower shield layer **9** that are disposed sandwiching the MR element **7** from the upper side and the lower side in the lamination direction. The MR element **7** may have any configuration utilizing a magneto resistive effect, such as for example a current in plane (CIP)-giant magneto resistive (GMR) element in which a sense current flows in the direction parallel to the film surface, a current perpendicular to plane (CPP)-giant magneto resistive (GMR) element in which a sense current flows in the direction perpendicular to the film surface (the lamination direction), or a tunneling magneto resistive (TMR) element that utilizes a tunnel effect, or the like. When a CPP-GMR element or a TMR element is used as the MR element **7**, the upper shield layer **8** and the lower shield layer **9** are also utilized as electrodes for supplying the sense current.

The slider **5** includes the magnetic recording element **21** for a so-called perpendicular magnetic recording as the recording head part. The magnetic recording element **21** has a pole **10** for recording. The pole **10** has a first body part **10***a*, a second body part **10***b*, and a pole tip part **10***c*, all of which are formed of, for example, an alloy made of any two or three of Ni, Fe, and Co. A return shield layer **11** is disposed lower than the pole **10** in the lamination direction. The return shield layer **11** has a first body part **11***a* and a second body part **11***b*, both of which are also formed of an alloy made, for example, of any two or three of Ni, Fe and Co. The pole **10** and the return shield layer **11** are magnetically linked with each other via a contact part **12**. In the present embodiment, the return shield layer **11** is disposed lower than the pole **10** in the lamination direction; however, it may be also disposed upper than the pole **10** in the lamination direction. The overcoat layer **15**, made of Al_2O_3, is disposed upper than the pole **10** in the lamination direction.

Coils **13***a* and **13***b* are wound around the pole **10** being centered on the contact part **12**. Magnetic flux is generated at the pole **10** by a current applied to the coils **13***a* and **13***b* from the outside. The coils **13***a* and **13***b* are formed of a conductive material such as Cu, etc. The coils **13***a* and **13***b* in the present embodiment are disposed in a two-layer manner; however one layer or three or more layers are also practical. Furthermore, the number of windings is four in the present embodiment; however the number is not limited to four.

The pole **10** is tapered at the pole tip part **10***c* in the vicinity of the ABS not only in the direction orthogonal to a film surface (the z-direction) but also in a cross track direction (the x-direction). Magnetic flux **17** generated in the pole **10** is tapered as it travels toward the ABS, and the minute and strong magnetic flux **17** for writing, which is suitable for high recording density, is discharged toward the magnetic recording medium **14** from the pole tip part **10***c* positioned on the ABS. The magnetic recording medium **14** has a configuration for perpendicular magnetic recording. A surface layer of the magnetic recording medium **14** is a recording layer **14***a*. The magnetic flux **17** discharged from the pole tip part **10***c* travels through the recording layer **14***a* in the perpendicular direction (the y-direction), and magnetizes each recording bit **14***b* of the recording layer **14***a* in the perpendicular direction. After the magnetic flux **17** passes through the recording layer **14***a*, the magnetic path of the magnetic flux **17** turns in an in-plane direction (the z-direction) of the magnetic recording medium **14** in an under layer **14***c* underneath made from a soft magnetic body. Furthermore, the direction of the magnetic flux **17** changes to the perpendicular direction (the y-direction) again in the vicinity of the return shield layer **11**, and the magnetic flux **17** is absorbed by the return shield layer **11**. In other words, the return shield layer **11**, illustrated in FIG. **3**, functions to control the magnetic flux **17** such that the magnetic flux **17** passes perpendicularly through the recording layer **14***a* and creates the U-shaped magnetic path.

In the pole **10** of the present embodiment, at least a portion that contacts the bank layer **30** has a reverse-triangle shaped portion along the plasmon generator **16** and the bank layer **30** on the ABS

Furthermore, the second body part **11***b* of the return shield layer **11** forms a trailing shield part whose layer cross section is wider in the cross track direction (the x-direction) than the first body part **11***a*. The placement of such a return shield layer **11** causes a steeper gradient of the magnetic field between the return shield layer **11** and the pole **10** in the vicinity of the ABS. As a result, signal output jitter is reduced and an error rate at the time of reading is decreased.

The waveguide **2** and the plasmon generator **16** are disposed between the pole **10** and the return shield layer **11**. The waveguide **2** is configured with the core **3** and the cladding **4** surrounding the core **3**. The core **3** has a higher refractive index than the cladding **4**. Laser light **19** (see FIG. **4**), entering from an LD **28** into the core **3**, is tapered by a spot size converter that is a tapered shape part of the core **3** while reflecting completely off the interface with the cladding **4**, and propagates toward the ABS. The cladding **4** is formed of, for example, AlO_x. The core **3** is formed of, for example, TaO_x. Herein, AlO_x indicates aluminum oxide of arbitrary composition, and Al_2O_3 is typical; however, AlO_x is not limited to this. Similarly, TaO_x indicates tantalum oxide of arbitrary composition, and Ta_2O_5, TaO, TaO_2, etc. are typical; however, TaO_x is not limited to these. In order to connect to the LD **28**, the core **3** extends from the ABS to a back surface **5***a* of the slider **5**. In addition, although not illustrated in the drawings, the cladding **4** exists between the core **3** and the contact part **12** as well.

The plasmon generator **16** is positioned away from the substrate **6**, and extends to the ABS facing a part of the core **3**. The plasmon generator **16** is formed of Au, Ag, Cu or the like. The bank layer **30**, made of an insulator protruding toward the ABS side relative to the plasmon generator **16**, is disposed between the plasmon generator **16** and the pole **10**. The bank layer **30** of the present embodiment is configured in a V-shape along the plasmon generator **16** on the ABS and a cross section parallel thereto.

Herein, a description of the plasmon generator **16** will be given. The plasmon generator **16** in the present embodiment is a V-shaped metallic piece that protrudes toward the core **3** on the ABS and the cross sections parallel thereto as illustrated in FIG. **1**A. An apex, facing the core **3**, of the V-shaped plasmon generator **16** configures a propagation edge **20***a* extending in a longitudinal direction (the y-direction) of the plasmon generator **16**. A buffer portion **32** is a portion sandwiched by the core **3** and a bottom surface including the propagation edge **20***a* of the plasmon generator **16**. In other words, the propagation edge **20***a* is covered by the buffer portion **32**. The buffer portion **32** functions to couple the propagation light propagating through the core **3** with the plasmon generator **16** in the surface plasmon mode. The near-field-generator **16***a* is formed at an edge part on the ABS of the propagation edge **20***a*.

Because of such a configuration, as illustrated in FIG. **4**, the plasmon generator **16**, at the overlapping part **22** where the propagation edge **20***a* overlaps the core **3** and due to the function of the buffer portion **32**, couples to propagation light **19** propagating through the core **3** in the surface plasmon mode, and generates a surface plasmon **23**. The generated surface plasmon **23** propagates toward the ABS along the propagation edge **20***a* and reaches the near-field-generator **16***a*. Then, the propagating surface plasmon **23** generates near-field light **24** at the near-field-generator **16***a*.

The plasmon generator **16** extends approximately parallel to the core **3** and in a direction (y-direction) perpendicular to the ABS. As illustrated in FIGS. **3** and **4**, the plasmon generator **16** does not extend to the back surface **5***a* of the slider **5**.

As illustrated in FIG. **3**, the LD **28** that is a light source is linked with the back surface (light incident surface) **5***a* of the slider **5**. The LD **28** has a pair of electrodes **25***a* and **25***b*, a positive (P) type cladding **26***a* and a negative (N) type cladding **26***b* that are sandwiched by the electrodes **25***a* and **25***b*, and an active layer **27** positioned between both of the claddings **26***a* and **26***b*, and these cleavage surfaces are in a reflecting mirror structure. The LD **28** is mounted on an LD sub-mount **29**, and is aligned properly with respect to the slider **5**. The active layer **27** that continuously oscillates the laser light **19** is positioned on the same line as the core **3** of the slider **5** such that the laser light **19** generated in the active layer **27** enters into the core **3**. The wavelength of the laser light **19** is not particularly limited; but laser light having a wavelength of approximately 800 nm is preferably used.

The core **3** of the waveguide **2** may have a square pillar shape extending in the same cross sectional shape; on the other hand, the core **3** of the waveguide **2** may be configured with the spot size convertor and a straight part. The spot size convertor is gradually tapered from the back surface **5***a* side of the slider **5**, i.e., from a side of the LD **28**. The straight part is positioned on the ABS side. As one example, a diameter of the propagation light **19** propagating through the core **3** is tapered when the propagation light **19** passes through the spot size converter having a length of approximately 100 μm or less, and the propagation light **19** enters into the straight part having a rectangular cross section of a width 0.4 μm×a height 0.5 μm.

When magnetic recording is performed to the magnetic recording medium **14** utilizing the thermally-assisted magnetic head **1** that is structured as above, power is supplied to a pair of the electrodes **25***a* and **25***b* of the LD **28**, which are linked with the back surface **5***a* of the slider **5**, and then the active layer **27** generates the laser light **19** and the laser light **19** enters into the core **3** facing the active layer **27**. The incident laser light **19** propagates toward the ABS in the core **3** as the diameter is tapered in the spot size converter. At the overlapping part **22** overlapping with the core **3**, the plasmon generator **16** couples to the propagation light **19** propagating through the core **3** in the surface plasmon mode due to the function of the buffer portion **32**, and generates the surface plasmon **23**. The surface plasmon **23** propagates along the propagation edge **20***a* of the plasmon generator **16** and reaches the near-field-generator **16***a*. The near-field light **24** is generated based on the surface plasmon **23** at the near-field-generator **16***a*. A portion (a portion to which information is recorded) of the recording layer **14***a* of the magnetic recording medium **14** is heated by this near-field light **24**, and the coercive force is decreased. Then, simultaneously with this heating, current is applied to the coils **13***a* and **13***b*, magnetic flux is generated in the pole **10**, and the information is written. Since the near-field-generator **16***a* that performs the heating and the pole **10** that performs the writing are closely positioned, the information is efficiently written to the portion of the recording layer **14***a* of the magnetic recording medium **14** where the coercive force is decreased due to the heating.

The plasmon generator **16** including the near-field-generator **16***a* on one edge part contributes to heat the magnetic recording medium **14**, so that the plasmon generator **16** itself is likely to be heated and heat-expanded. However, with the configuration of the present embodiment, the plasmon generator **16** does not extend over the bank layer **30** on the ABS even when the plasmon generator **16** is heat-expanded as illustrated in FIG. 2C. In other words, the bank layer **30** that protrudes relative to the plasmon generator **16** blocks a progression of the plasmon generator **16** toward the pole **10** side. Therefore, an electrical short due to the contact between the pole **10** made of the base metal and the plasmon generator **16** made of the noble metal is prevented, and the corrosion of the pole **10** is suppressed.

Next, one example of a manufacturing method of the thermally-assisted magnetic head **1** of the present embodiment will be explained. Additionally, detailed explanation of each process to which a known method may be arbitrarily applied is omitted.

Initially, as illustrated in FIG. **2**, the lower shield layer **9**, the MR element **7** that is a reproducing element, the upper shield layer **8** and the return shield layer **11** are laminated in this order above the substrate **6** that is made of Al_2O_3.TiC. Additionally, in the middle of this process, insulation layers are appropriately disposed respectively between the lower shield layer **9** and the upper shield layer **8** and between the upper shield layer **8** and the return shield layer **11**.

Next, the cladding **4** made of AlO_x and the core **3** made of TaO_x are laminated in this order, and patterning is performed. Propagation of single mode light is necessary to induce the near-field light; and a cross sectional size of the core **3** should be a wavelength of the propagation light **19** or less, although it is dependent on refractive indices of the core **3** and the cladding **4**. In the present example, a patterning is performed on the core **3** such that an edge surface exposed on the ABS becomes a rectangle of width 0.4 μm×height 0.5 μm, and it is arranged such that the laser light **19** having the wavelength of 0.8 μm propagates. In the figures, the cladding **4** that is formed beforehand and the cladding **4** that is newly laminated are illustrated in an integrated manner.

The cladding **4** that is a dielectric spacer layer is formed above the core **3**, and a V-shaped groove is formed on an upper surface of the cladding **4**. The plasmon generator **16** made of Au is formed in the groove. The plasmon generator **16** has a V-shaped cross section that corresponds to the shape of the groove.

The bank layer **30** made of alumina is formed on the plasmon generator **16**. One example of the thickness of the bank layer **30** is 2 nm.

The pole **10** is formed thereabove. A lower part of the pole **10** is formed in a reverse-triangle shaped portion along the shape of the plasmon generator **16** and the bank layer **30**. In other words, the pole **10** that is configured with the reversed-triangle-shaped lower portion and a quadrangle-shaped upper portion is formed on the V-shaped plasmon generator **16** and the bank layer **30**. The cladding **4** is formed surrounding the plasmon generator **16**, the bank layer **30**, and the pole **10**. Then, the coil layers **13***a* and **13***b* and the overcoat layer **15**, which are illustrated in FIG. **2**, are formed.

Ion milling is performed on the slider **5** formed as described above, and an ABS facing the magnetic recording medium **14** is formed. At this point, the plasmon generator **16** is recessed from the ABS. A desired recession length of the plasmon generator (i.e., a desired protruding length of the bank layer **30**) is obtained by varying conditions of the ion milling, such as, for example, composition of atmosphere gas, application voltage, performing duration, milling angle, etc., in accordance with materials of each layer including the plasmon generator **16**.

Thereafter, the LD unit **18** including the LD **28** that generates laser light having a wavelength of 800 nm is attached to the slider **5** performing an alignment to link the LD **28** with the core **3** of the waveguide **2**.

A writing experiment was performed with the thermally-assisted magnetic head **1** of the embodiment of the present invention, which is manufactured as described above. Specifically, thermally-assisted magnetic recording was performed to the magnetic recording medium **14** using the magnetic recording element **21**, the recorded magnetic information was simultaneously reproduced by the MR element **7** that is adjacent thereto, and reproduced output was measured. Light power that is required for saturation recording and corrosion time of the pole were then determined. Additionally, the experiment was performed as a magnetic flux variation number per 1 inch (2.54 cm) was 500 kFCI and rotation speed of the magnetic recording medium was 3600 rpm.

Herein, the saturation recording will be explained. When light power of laser light that is introduced into the core **3** for the thermally-assisted magnetic recording is increased, output of the MR element **7** at the time of reading magnetic information recorded by the thermally-assisted magnetic recording is increased. When the light power of the laser light reaches a certain amount, the output of the MR element **7** at the time of reading the magnetic information becomes approximately constant, and the output does not increase further (see FIG. **5**). The output of the MR element **7** at this point is referred to as a saturation output. A reason for reaching a saturation recording state will be explained. When the magnetic recording medium is not sufficiently heated, coercive force is not sufficiently reduced. As a result, a magnetization in one recording bit does not become identical to those in the others, and an even magnetization state is not provided over an entirety of the recording bit even when the same magnetic flux is applied. However, since the coercive force is sufficiently reduced when the heating is sufficient, magnetization reversal evenly occurs and the magnetizations become identical over the entirety of the recording bit. When the magnetizations are evenly identical, variation in the magnetization state does not occur even though further heating is performed, and the saturation recording state is provided. The reproduced output and heat quantity for heating the medium to reach the saturation recording have a positive correlation. Then, the heat quantity for heating the medium may be represented by power supplied to the LD **28**. When the saturation recording state having a large reproduced output is accomplished with small power, this provides high energy efficiency and also an advantage that the longevity of LD **28** is increased.

With the above-described manufacturing method, a plurality of thermally-assisted magnetic heads **1** were manufactured, each of which had a different protruding length of the bank layer **30** relative to the plasmon generator **16**, and an amount of power supplied to the LD **28** which is required to reach a corresponding saturation recording was determined, for each thermally-assisted magnetic head **1**. FIG. **6** illustrates results thereof. According to FIG. **6**, when the protruding length of the bank layer **30** relative to the plasmon generator **16** was 5 nm or less, the power required to reach the saturation recording was approximately constant; on the other hand, when the protruding length was 6 nm or more, the required power increased largely, which is not preferred. It is assumed that this is caused by that the plasmon generator **16** that has a small propagation loss of the surface plasmon disappears in the vicinity of the ABS, and that a propagation loss starts to emerge when a distance (the protruding length of the bank layer **30**) of which an area where the bank layer **30** exists but the plasmon generator **16** does not exist extends in a direction orthogonal to the ABS is 6.0 nm or more. Therefore, from the standpoint of power required to reach the saturation recording, it is preferred that the protruding length of the bank layer **30** relative to the plasmon generator **16** is 5 nm or less.

Similarly, the present applicant manufactured a plurality of thermally-assisted magnetic heads **1**, each of which had a different protruding length of the bank layer **30** relative to the plasmon generator **16**, and measured time until the pole **10** corroded (corrosion time of pole). Specifically, recording of the magnetic information by the magnetic recording element **21** and reproducing by the MR element **7** were continued from a point of reaching the above-described saturation recording, without varying power supplied to the LD **28**. Then, the point when the measured reproduced output was reduced by 10% was defined as "the magnetic pole **10** corroded." A continuous writing time required to corrode the pole **10**, which is referred to as "corrosion time of pole," is illustrated in FIG. **6**. Additionally, as shown in FIG. **6**, the corrosion time of pole of each of the thermally-assisted magnetic heads **1** is described with a relative value according to that the corrosion time of pole of the thermally-assisted magnetic head **1** having 0 nm of the protruding length of the bank layer **30** relative to the plasmon generator **16** is one. Referring to FIG. **6**, compared to the thermally-assisted magnetic head **1** having 0 nm of the protruding length of the bank layer **30** relative to the plasmon generator **16**, the corrosion time of pole approximately quintuples when the protruding length is 0.5 nm, and the corrosion time of pole approximately decuples when the protruding length is 1-5 nm. Accordingly, when the bank layer **30** protrudes relative to the plasmon generator **16** even by just a small amount, corrosion resistance is largely improved.

When the protruding length of the bank layer **30** relative to the plasmon generator **16** is 6 nm or more, the corrosion time of pole is shortened. It is estimated that this may be due to the fact that the propagation loss starts to emerge when the protruding length of the bank layer **30** relative to the plasmon generator **16** is 6.0 nm or more as described above, heat generation in the vicinity of the ABS increases corresponding thereto, and an oxidation reaction of the pole **10** is accelerated.

[Second Embodiment]

FIG. **7** illustrates a thermally-assisted magnetic head **1** of a second embodiment of the present invention in which a bank layer **30** protrudes from an ABS. Similar to the first embodiment, the thermally-assisted magnetic head **1** of the second embodiment also produces effects that corrosion time of pole extends as well as power required to reach saturation recording is reduced, and that is the contribution to high recording density as well as the suppression of the pole corrosion.

The manufacturing method of the thermally-assisted magnetic head **1** of the present embodiment is substantially the same as the manufacturing method of the first embodiment. In the step of ion milling, all layers other than the bank layer **30** on the ABS are recessed, which is the only different aspect from the first embodiment in which only the plasmon generator **16** is recessed.

The present applicant manufactured a plurality of the thermally-assisted magnetic heads **1**, each of which had a different width of the bank layer **30**, performed the writing experiment which was the same as the one performed in the first embodiment, and determined corrosion time for pole. FIG. **8** illustrates results thereof. The experimental conditions were the same as described above, and the protruding length of the bank layer **30** was constantly set to 2 nm.

According to FIG. **8**, it is determined that when the thickness of the bank layer **30** made of alumina is 1 nm or more, the corrosion time of pole is significantly extended, or in other words, output deterioration due to the corrosion of the pole **10** is suppressed. Only the bank layer **30** made of alumina is explained herein; however, it is estimated that a bank layer, made of a material that is generally classified as an insulator, contributes to the improvement in a corrosion resistance of the pole **10** when the thickness is approximately 1 nm or more as well.

[Third Embodiment]

FIG. **9** illustrates a thermally-assisted magnetic head **1** of a third embodiment of the present invention in which a bank layer **30** protrudes from an ABS and a plasmon generator **16** is recessed from the ABS. Similar to the first and second embodiments, the thermally-assisted magnetic head **1** of the third embodiment also produces effects that corrosion time of pole extends as well as power required to reach saturation recording is reduced, and that is the contribution to high recording density as well as the suppression of the pole corrosion.

The manufacturing method of the thermally-assisted magnetic head **1** of the present embodiment is substantially the same as the manufacturing method of the first and second embodiments. All layers other than the bank layer **30** on the ABS are recessed in the step of ion milling, and only the plasmon generator **16** is largely recessed, which are the different aspects from the first and second embodiments.

The choice of materials used for each layer determines which the thermally-assisted magnetic head **1** of either the above-described first, second or third embodiments is manufactured. Then, it is possible to vary the protruding length of the bank layer **30** by adjusting the condition of ion milling (a composition of atmosphere gas, application voltage, performing duration, milling angle, etc). Particularly, from the standpoint of suppressing the corrosion of the pole **10**, it is not a serious matter which configuration is applied; the configuration in which the bank layer **30** protrudes from the ABS, the configuration in which the plasmon generator is recessed from the ABS, or a configuration incorporating both of the previously mentioned configurations. The important point is a distance between the edge part of the bank layer **30** and the edge part of the plasmon generator **16**. When the distance between both of them, i.e., the protruding length of the bank layer **30** relative to the plasmon generator **16** is 0 nm (exclusive) to 5 nm (inclusive), or more preferably 1 nm (inclusive) to 5 nm (inclusive), the effect to suppress the corrosion of the pole **10** is large. This is common in all of the first, second and third embodiments. Similarly, when the thickness of the bank layer **30** is 1 nm or more, the corrosion of the pole **10** is effectively suppressed in all of the first, second and third embodiments.

As a material to the plasmon generator **16** of the thermally-assisted magnetic head **1** of the present invention, Au, Ag, Cu, Pd, Ir, Pt and a substance that is made primarily of these materials are applicable, and specifically Au, Ag, Cu are typical.

As a material to the bank layer **30**, BO_x, AlO_x, MgO, SiO_x, TiO_x, VO_x, CrO_x, MnO_x, FeO_x, CoO_x, NiO_x, ZnO_x, GaO_x, GeO_x, YO_x, ZrO_x, NbO_x, MoO_x, InO_x, SnO_x, SbO_x, HfO_x, TaO_x, BiO_x, CeO_x, NdO_x, SmO_x, GdO_x, TbO_x, DyO_x, YbO_x, BN, AlN, SiN_x, TiN_x, FeN_x, GaN_x, ZrN_x, TaN_x, WN_x, MgF, Si, SiC, TaC, AlON, SiON, AlSiON or substances made primarily of these materials ("x" is an arbitrary number) are applicable. Specifically, AlO_x, MgO, SiO_x, TiO_x, ZnO_x, HfO_x, TaO_x, AlN, SiN_x, MgF, Si, SiC, TaC, AlON, SiON, AlSiON are typical.

As illustrated in FIG. **1**A, the present invention is not limited to the configuration having the V-shaped plasmon generator **16**. The present invention is also applicable to the configuration having the reverse-triangle shaped plasmon generator **16** as illustrated in FIG. **10**.

Furthermore, the present invention is not limited to the thermally-assisted magnetic head **1** using evanescent light. As long as a thermally-assisted magnetic head has the plasmon generator **16** that is exposed on the ABS and that generates the near-field light and has the pole **10** close to the plasmon generator **16**, the thermally-assisted magnetic head is widely applicable.

For mass-manufacturing the thermally-assisted magnetic heads **1**, a plurality of stacks configuring the slider **5** are formed on a wafer **100** illustrated in FIG. **11**. The wafer **100** is divided into a plurality of bars **101**, which are working units for the polishing process of the ABS. The bar **101** is further cut after the polishing process and is divided into the plurality of sliders **5**. Margins for cutting (not illustrated) that are for cutting the wafer **100** into the bar **101** and for cutting the bar **101** into the slider **5** are formed in the wafer **100**. As illustrated in FIG. **12**, each of the sliders **5** has an approximately hexahedral shape, and one surface of the six outer surfaces is the ABS facing a hard disk **14** that is a recording medium. The LD unit **18** aligned with respect to the slider **5** is attached to the slider **5**, and the thermally-assisted magnetic head **1** is configured.

Referring to FIG. **13**, a head gimbal assembly **220** includes the thermally-assisted magnetic head **1** and a suspension **221** elastically supporting the thermally-assisted magnetic head **1**. The suspension **221** has a load beam **222**, a flexure **223**, and a base plate **224**. The load beam **222** is formed in a plate spring shape and made of stainless steel. The flexure **223** is arranged in one edge part of the load beam **222**. The base plate **224** is arranged in the other edge part of the load beam **222**. The flexure **223** is joined to the thermally-assisted magnetic head **1** to give the thermally-assisted magnetic head **1** suitable flexibility. At the part of the flexure **223** to which the thermally-assisted magnetic head **1** is attached, a gimbal part is disposed to maintain the thermally-assisted magnetic head **1** in an appropriate orientation.

The thermally-assisted magnetic head **1** is arranged in the hard disk device such that the thermally-assisted magnetic head **1** faces the hard disk **14** which is a disk-shaped recording medium that is rotatably driven. When the hard disk **14** rotates in the z-direction of FIG. **13**, air flow passing between the hard disk **14** and the thermally-assisted magnetic head **1** generates a downward lifting force in the y-direction to the thermally-assisted magnetic head **1**. The thermally-assisted magnetic head **1** flies from the surface of the hard disk **14** due to the lifting force. At the edge part of the slider **5** of the thermally-assisted magnetic head **1** on the air flow exit side (a left side of FIG. **12**), the magnetic recording element **21** is formed.

A part in which the head gimbal assembly **220** is mounted on an arm **230** is referred to as a head arm assembly **221**. The arm **230** moves the thermally-assisted magnetic head **1** in the track crossing direction x of the hard disk **14**. One edge of the arm **230** is mounted on the base plate **224**. On the other edge of the arm **230**, a coil **231** is mounted, which forms one part of a voice coil motor. A bearing part **233** is arranged in the middle section of the arm **230**. The arm **230** is rotatably supported by a shaft **234** mounted on the bearing part **233**. The arm **230** and the voice coil motor for driving the arm **230** configure an actuator.

Next, referring to FIGS. **14** and **15**, a head stack assembly in which the above-described thermally-assisted magnetic head **1** is integrated and the hard disk device will be explained. A head stack assembly refers to a component in which the head gimbal assemblies **220** are mounted on each arm of a carriage that has a plurality of the arms. FIG. **14** is a side view of the head stack assembly. FIG. **15** is a plan view of the hard disk device. The head stack assembly **250** includes a carriage **251** having a plurality of arms **252**. On each of the arms **252**, the head gimbal assembly **220** is mounted so that the head gimbal assemblies **220** align with an interval in the vertical direction. At the opposite side of the arm **252** from the carriage **251**, the coil **253** is mounted to be a part of the voice coil motor. The voice coil motor has permanent magnets **263** positioned sandwiching the coil **253** and facing each other.

Referring to FIG. **15**, the head stack assembly **250** is integrated in the hard disk device. The hard disk device has multiple hard disks **14** mounted on a spindle motor **261**. On each of the hard disks **14**, two sliders **5** are arranged in a manner of sandwiching the hard disk **14** and facing each other. The head stack assembly **250** except for the thermally-assisted magnetic head **1** and the actuator, corresponding to a positioning device of the present invention, not only support the thermally-assisted magnetic head **1** but also position the thermally-assisted magnetic head **1** with respect to the hard disk **14**. The thermally-assisted magnetic head **1** is moved in the track crossing direction of the hard disk **14** by the actuator, and is positioned with respect to the hard disk **14**. The magnetic recording element **21** included in the thermally-assisted magnetic head **1** records information to the hard disk **14**, and the MR element **7** reproduces the information recorded on the hard disk **14**.

While preferred embodiments of the present invention have been shown and described in detail, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the spirit or scope of the following claims.

What is claimed is:

1. A thermally-assisted magnetic head that has an air bearing surface (ABS) facing a recording medium and that performs magnetic recording while heating the recording medium, comprising:

a magnetic recording element that includes a pole of which an edge part is positioned on the ABS and which generates magnetic flux traveling to the recording medium;

a waveguide that is configured with a core through which light propagates and a cladding, surrounding a periphery of the core, at least one part of which extends to the ABS;

a plasmon generator that faces a part of the core and that extends toward the ABS side; and

a bank layer that is positioned between the plasmon generator and the pole, and of which an edge part on the ABS side protrudes relative to the plasmon generator.

2. The thermally-assisted magnetic head according to claim **1**, wherein

an edge part of the plasmon generator on the ABS side is recessed relative to the all other parts on the ABS.

3. The thermally-assisted magnetic head according to claim **1**, wherein

the edge part of the bank layer on the ABS side protrudes relative to the all other parts on the ABS.

4. The thermally-assisted magnetic head according to claim **1**, wherein

an edge part of the plasmon generator on the ABS side is recessed relative to the all other parts on the ABS, and the edge part of the bank layer on the ABS side protrudes relative to the all other parts on the ABS.

5. The thermally-assisted magnetic head according to claim **1**, wherein

the plasmon generator has a V-shaped portion that protrudes toward the core on the ABS;

the bank layer has a V-shaped portion along the plasmon generator on the ABS; and

at least a portion of the pole contacting the bank layer is in a reverse-triangle shape along the plasmon generator and the bank layer on the ABS.

6. The thermally-assisted magnetic head according to claim **5**, wherein

a protruding length of the bank layer relative to the plasmon generator is not less than 0.5 nm and not more than 5 nm.

7. The thermally-assisted magnetic head according to claim **6**, wherein

a layer thickness of the bank layer is 1 nm or more.

8. The thermally-assisted magnetic head according to claim **5**, wherein

the plasmon generator includes a propagation edge extending in a longitudinal direction;

the propagation edge includes an overlapping part that overlaps the core in the longitudinal direction and near-field-generator that faces the core and that is positioned in the vicinity of the edge part of the pole on the ABS;

the overlapping part of the propagation edge couples to laser light propagating through the core in surface plasmon mode and generates surface plasmon; and

the propagation edge propagates the surface plasmon generated in the overlapping part to the near-field-generator.

9. The thermally-assisted magnetic head according to claim **1**, wherein

a position of the edge part of the bank layer on the ABS side is closer to the recording medium than a position of the plasmon generator relative to the recording medium.

10. The thermally-assisted magnetic head according to claim **1**, wherein

the bank layer protrudes in a direction perpendicular to the ABS.

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